JOURNAL
OF THE
AMERICAN WATER WORKS ASSOCIATION

Vol. 34 APRIL 1942 No. 4

Contents

All correspondence relating to the publication of papers should be addressed to

Harry E. Jordan, Secretary
22 East 40th St., New York

$7.00 of Members dues are applied as subscription to the Journal
Additional single copies to members—50 cents
Single copies to non-members—75 cents

THIS W&T

Safety Service

GIVES YOU

HEALTH DEFENSE ... today

Wallace & Tiernan representatives are on the job to help you increase the safety of water supplies against possible air raids, sabotage and other emergency conditions. Their suggestions are based on information obtained from "blitzed" areas in England, as well as from American military and civilian defense authorities. They can advise on procedures already being followed at critical coastal points.

A safety check-up of your present chlorinating facilities and operating methods may reveal simple changes that make for greater safety.

Where new equipment is needed for essential jobs such as secondary chlorination of open distribution reservoirs, emergency sterilization of broken mains, and the like, you will find W&T ready to be of service with complete data, equipment and service.

BUDGET DEFENSE ... tomorrow

As you equip yourself to assure higher standards of safety for the war emergency, remember that an investment in W&T chlorinating equipment has sound peacetime value as well. Today's acute public consciousness of the need for safe water can be acted upon with full confidence that you're making a constructive move for the future.

Protection against floods, fires and other natural emergencies will always be necessary. Moreover, problems of taste and odor control, and other water treatment steps required for improved palatability, can usually be met by the same highly flexible equipment now so necessary to safeguard health.

Your W&T Representative will work with you in extending your chlorination facilities in a way that's soundly planned for long term satisfaction and low operating expense. Call him today, or write direct for Technical Bulletins giving facts and figures. SA-131-S

We'll be seeing you at
The A.W.W.A. Convention
STEVENS HOTEL • CHICAGO
JUNE 21 — 25, 1942

"The Only Safe Water is a Sterilized Water"

WALLACE & TIERNAN CO., Inc.

MANUFACTURERS OF CHLORINE AND AMMONIA CONTROL APPARATUS
NEWARK, NEW JERSEY • REPRESENTED IN PRINCIPAL CITIES

JOURNAL

OF THE

AMERICAN WATER WORKS ASSOCIATION

Copyright, 1942, by The American Water Works Association

Reproduction of the contents, either as a whole or in part, is forbidden, unless specific permission has been obtained from the Editor of this Journal. The Association is not responsible, as a body, for the facts and opinions advanced in any of the papers or discussions published in its proceedings.

Vol. 34 | April 1942 | No. 4

Relationship of Missouri River Navigation Improvements to Valley Properties

By F. S. Besson

THE Missouri River, from Sioux City to its mouth—the distance covered by the navigation project now in progress—lies in a great rock trough between adjacent hills, varying from two to seventeen miles apart. This trough, which many years ago filled with sand, gravel and boulders, today is covered with a loamy deposit of fertile bottom soil. Figure 1 shows how, throughout the years, the river shifted its alignment so that it occupied, at some time, every point between the limiting lines of hills. This constant change of channel has been due largely to the easily erodible banks together with the high-velocity current. Many former river towns have been left high and dry by this action, including: Rocheport, Arrowrock, Lisbon, Brunswick, DeWitt, Camden, Wellington, Parkville, Weston, Doniphan and Amazonia. As late as 1930 a considerable sum was spent in preventing the river from isolating the two bridges and town at Glasgow. The channel as shown in Fig. 1 represents conditions at St. Joseph but ten years ago.

Water may flow in a wide shallow stream, or the same quantity may be handled in a more confined stream with a greater depth. The excessive width of the unregulated Missouri River, with its constantly moving sandbars, jutting from shore, and constantly shifting islands, dividing the stream into uncertain channels, is obvious from Fig. 2. This map shows the river twenty miles below Sioux City, Iowa. The stream is shown as of 10 years ago. Navigation on a stream of this character is impracti-

---

A paper presented on October 21, 1941, at the Missouri Valley Section Meeting, Cedar Rapids, Iowa, by F. S. Besson, Colonel, Corps of Engrs., Div. Engr. Missouri River Div., Kansas City, Mo.

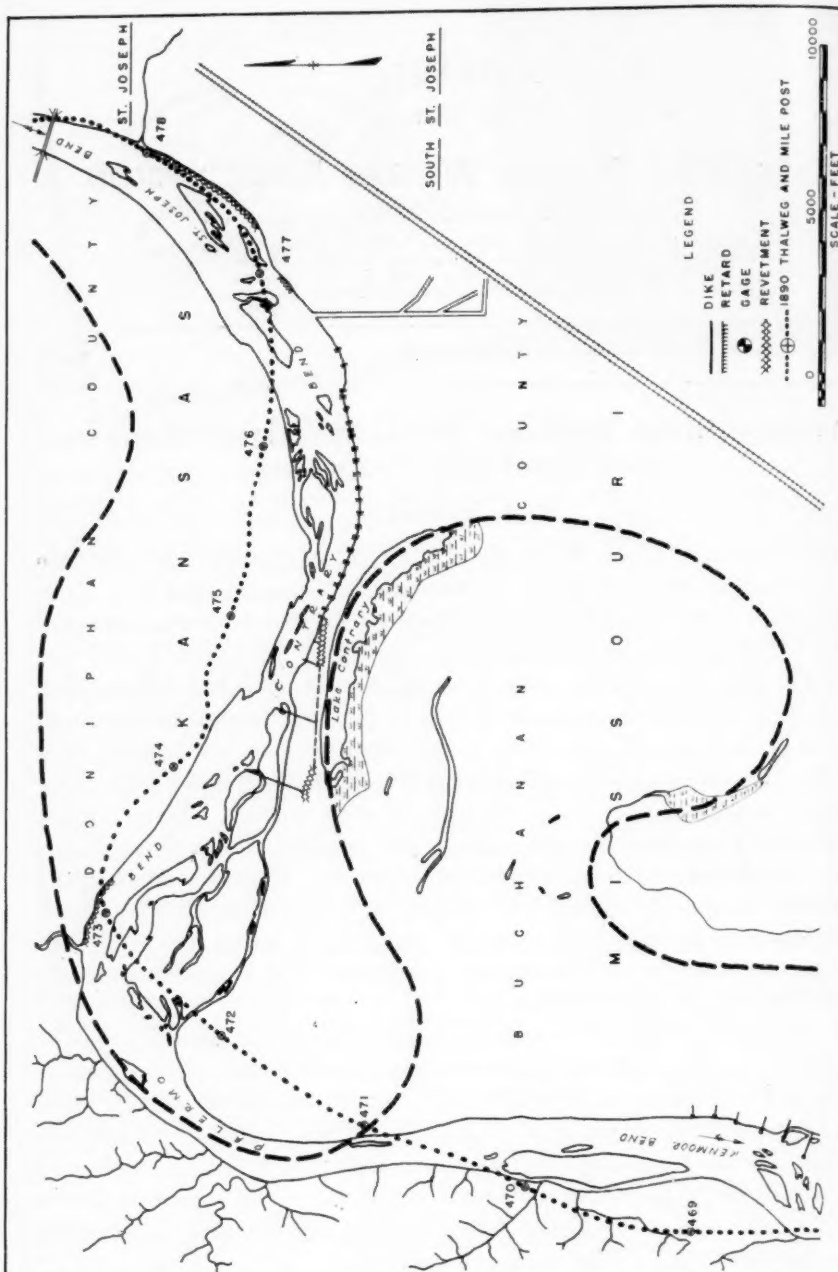

ST. JOSEPH
SOUTH ST. JOSEPH
ST. JOSEPH BEND
CONTRARY BEND
Lake Contrary
PALERMO BEND
KENMOOR BEND
BEND
DONIPHAN COUNTY
KANSAS
BUCHANAN COUNTY
MISSOURI
469
470
471
472
473
474
475
476
477
478
LEGEND
DIKE
RETARD
GAGE
REVETMENT
1890 THALWEG AND MILE POST
0
5000
10000
SCALE - FEET

FIG. 1

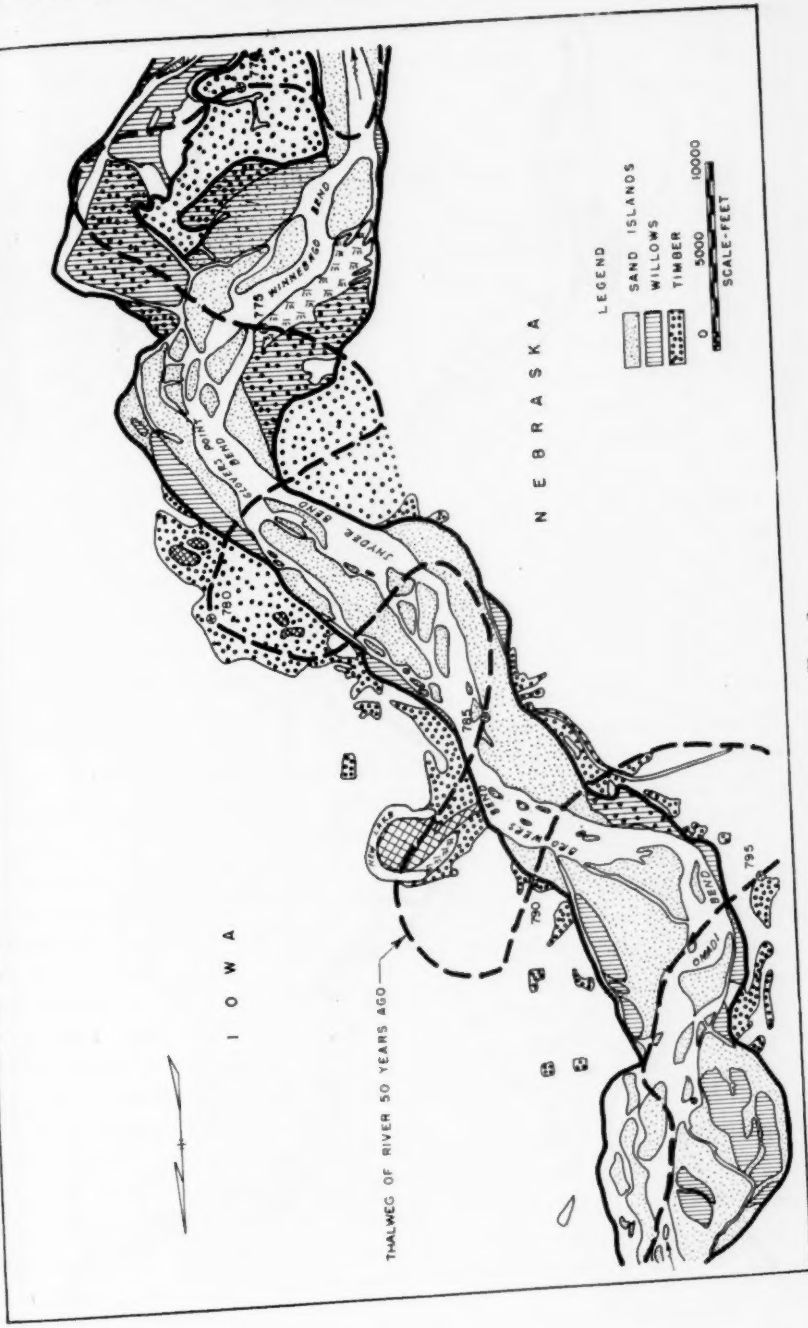

IOWA
NEBRASKA
LEGEND
SAND ISLANDS
WILLOWS
TIMBER
0 5000 10000
SCALE-FEET
THALWEG OF RIVER 50 YEARS AGO
775 WINNEBAGO BEND
SNYDER BEND
OMADI BEND
780
785
790
795

FIG. 2

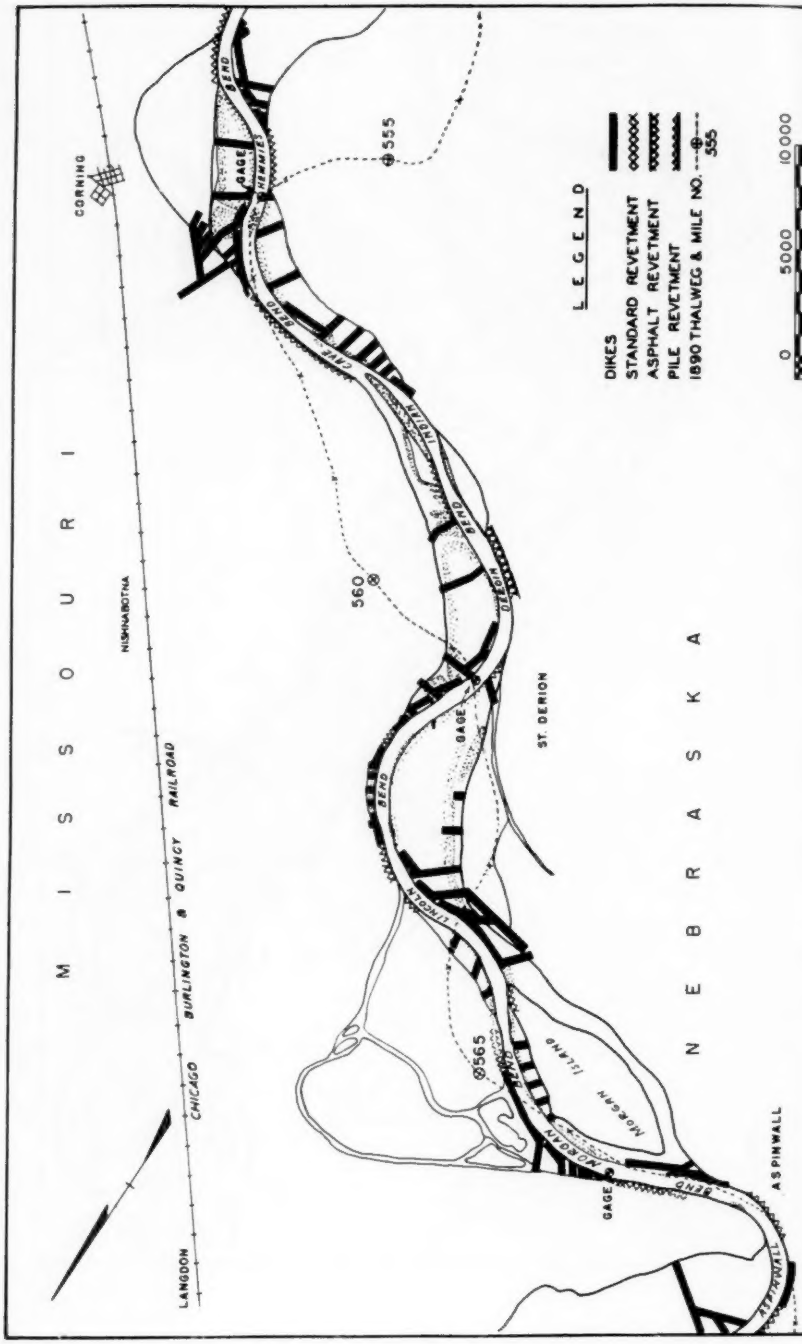

M I S S O U R I
N E B R A S K A
CHICAGO BURLINGTON & QUINCY RAILROAD
LANGDON
NISHNABOTNA
CORNING
GAGE
ASPINWALL
ST. DERION
ASPINWALL BEND
MORGAN BEND
MORGAN ISLAND
LINCOLN BEND
GAGE BEND
DESOTO BEND
INDIAN CAVE BEND
HEMMIES BEND
565
560
555
LEGEND
DIKES
STANDARD REVETMENT
ASPHALT REVETMENT
PILE REVETMENT
1890 THALWEG & MILE NO.
0 5000 10000
SCALE - FEET

FIG. 3

cable during low-water periods, even with craft of shallow draft. The actual banks of the stream are as much as 18,000 ft. apart, whereas, at this location, it is the aim of the project to confine it between banks only 700 ft. apart.

Navigation Objective

Thus arises the question of navigation objective. The objective of any transportation system, of course, is low unit cost, which for a freight system, is expressed in mills per ton-mile. In order of cost, from highest to lowest, the available traffic systems are: airplane, truck, rail, pipeline and waterway. That there is a field for each system of transportation must, of course, be realized. Some commodities are adaptable to transportation exclusively by one system, while others are more flexible. For those commodities which can be transported by waterway, however, that system is the most economical.

Obviously it is impossible to keep waterway transportation costs low unless a river is stabilized. In view of this, the plan calls for a low-water stream width, confined between banks, gradually increasing from 700 ft. at Sioux City to 1,100 ft. at its mouth. Within this full stream width it is, at present, planned to provide a 200-foot navigable channel, a 6-foot minimum depth on the crossings, with, of course, a greater depth in the pools. Provided that there is a sufficient depth and an efficient alignment, flood flows will be carried without appreciably increasing critical flood stages. A further project, already approved by the Chief of Engineers and pending before Congress, calls for a 300-foot channel with a 9-foot depth on the crossings. Such a waterway will provide much more economical transportation than the one now nearing completion.

Figure 3 demonstrates the method employed in stabilizing the river. A comparison of this diagram with Fig. 2 will indicate the extent to which the stream is confined. The permeable pile dikes lower the velocity of the current so that the stream drops part of its soil load between dikes. After each high water there is an increment to the making land, until, after a few high-water periods, the new land is level with the top of the structures, eventually reaching the elevation of the agricultural land behind the river banks.

By combinations of systems of S-curves, the channel alignment is directed from deep water along one concave bank to deep water along another, with a satisfactory depth on the crossings. To prevent erosion and maintain the alignment, the concave banks must be protected with rock or pile revetments, underlaid with lumber or willow mattresses, or other types of construction.

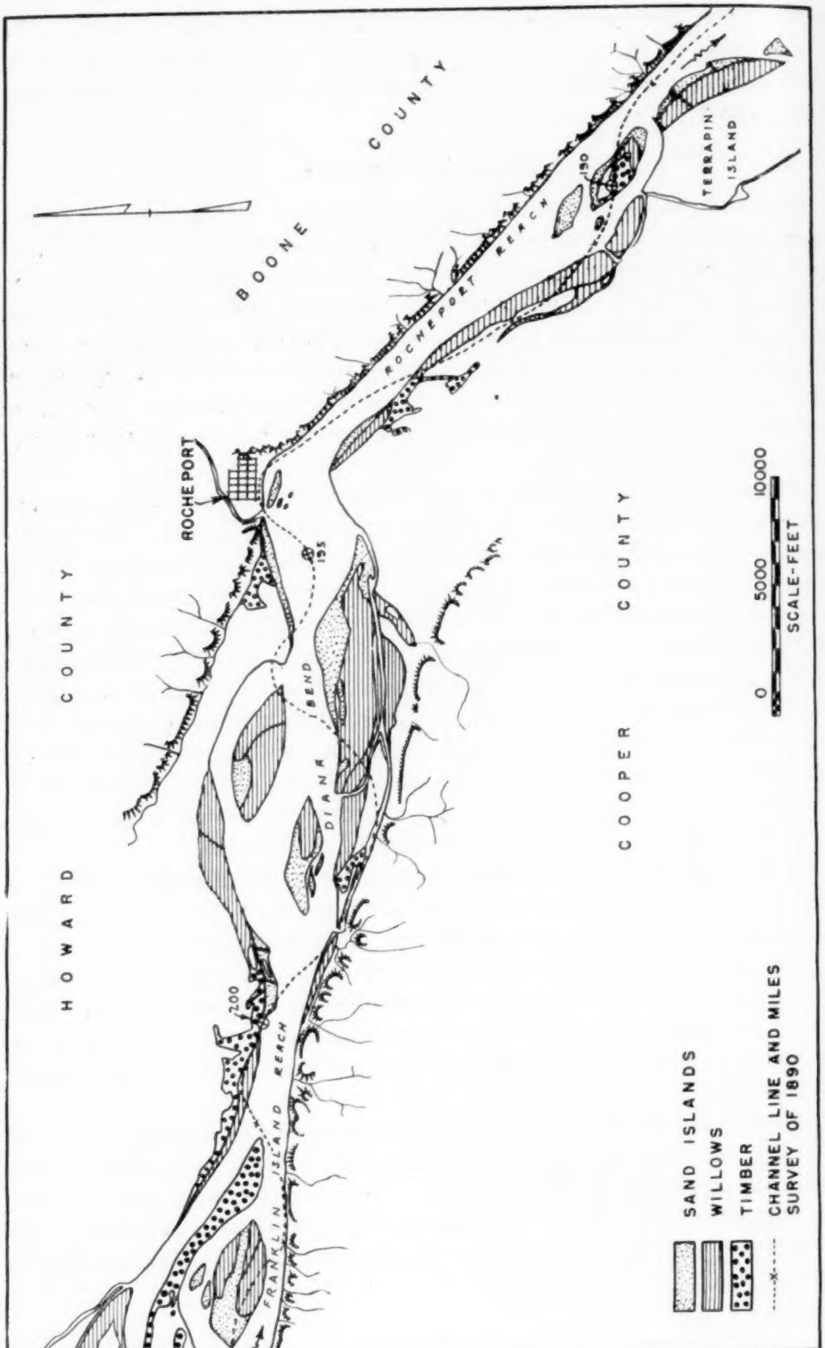

HOWARD COUNTY
BOONE COUNTY
COOPER COUNTY
ROCHEPORT
ROCHEPORT REACH
TERRAPIN ISLAND
DIANA BEND
FRANKLIN ISLAND REACH
190
195
200
0
5000
10000
SCALE-FEET
SAND ISLANDS
WILLOWS
TIMBER
CHANNEL LINE AND MILES SURVEY OF 1890

FIG. 4A

Fig. 4B

It has already been indicated how, years ago, the wild river wandered over the entire valley. Were all of the valley available today to the engineers drawing the stream alignment, a perfect plan could be drawn up. Industrial, commercial and agricultural progress, however, has developed values that cannot be ignored. Bridges, railroads, highways, city water intakes and highly developed farms must, if at all practicable, be left right where they are. These fixed points, together with the necessity of getting from the river, as it now exists, a satisfactory job at minimum cost, result in many compromises with the theory of design. Sometimes the fixed points are so located that no satisfactory compromise is possible. In those instances where the interests of navigation conflict with other interests to the extent that navigation would be seriously affected if full consideration were given to the fixed points, priority, as required by law, is given to the navigation interests. In those exceptional instances, private interests and public utilities must suffer consequential damages.

Supplemental Benefits

The incidental benefits received by riparian owners of land are of two types—one applying to land adjacent to the river and the other to land reclaimed within the banks of the wild stream. Where the river has not been stabilized, loan agencies will not grant loans on land lying within $3\frac{1}{2}$ miles of the banks of the stream. That such loans are made after the river is stabilized is indicative of the great increase in land values that takes place as a result of the project. In this respect, a study of land values has indicated that for the more than 1,000,000 acres affected, increases will approximate $50,000,000.

A comparison of Figs 4A and 4B will show how, by confining the river between relatively narrow banks, land is reclaimed and converted into productive farms. Eventually, more than 200,000 acres, with a value of more than $10,000,000, will be reclaimed in this way, extending from Sioux City to the river mouth. On the photograph (Fig. 4B) are indicated dikes which today are covered with fertile soil.

Prior to the stabilization work, private interests and public utilities spent many millions of dollars to protect their properties and developments from the ever-shifting river. With stabilization, water intakes may be installed in a permanent location with the reasonable assurance of a reliable supply of water. Bridges will be secure without continuous heavy maintenance expenditures. Commercial, industrial and municipal developments will be permanently protected.

A study of past destruction and damages shows that they are equivalent to an expenditure of more than $1,000,000 annually for maintenance, or of a capitalized cost of more than $25,000,000. Since a stabilized river does

away with these damages, the project may be credited with the saving in capital cost.

Figures 5A and 5B give an example of a water intake in the area affected. Before installation of the intake, the main flow lay along a chute to the north or left of Bonhomme Island, giving a concave bank and deep water at the site of the proposed intake. By 1924, the main flow had wandered to the south or right of Bonhomme Island, making the reach too long and too straight, so that the deep water then shifted to the north, away from the intake. A considerable expenditure has been charged directly to the efforts made to force the flow back to the intake. The dikes shown in Fig. 5A represent part of that expenditure—but an incorrect solution as it provided a reach or tangent. Because of fixed points, no S-curve could be designed to throw the flow back through the chute. The only practicable solution was to break the tangent and make a gentle S-curve, as shown in Fig. 5B.

A river cannot be forced into unnatural tangents by the construction of dikes along an isolated stretch. It must be stabilized by the construction of continuous natural S-curves. An incidental benefit to be obtained by dike construction is that the dikes become covered with fertile soil and thus available for farming. Not only is it impossible to maintain a long tangent, but the difficulties of attempting to throw the main flow against the convex bank are many.

In Fig. 6 is shown the St. Charles water intake—on the convex side of a bend. On an incorrect theory of development the engineers have, during the past ten years, endeavored to satisfy local wishes by dredging and constructing dikes to force the flow along this convex bank. At no time, however, could satisfactory results at the intake be assured. The tangent involved was too long, and with the bridges as two fixed points no S-curve that would result in a concave bank and deep water at the intake could be designed. The only solution was to make the concave bank at some distance from the original intake, cutting through the old dikes and placing a new intake in the bend. S-curve alignment must be maintained, and deep water can be expected only in the concave bends.

To recapitulate the benefits of a stabilized river, estimates show that, with a 9-foot depth, approximately 12,000,000 tons of freight representing about three or four billion ton-miles, should move on the Missouri River. The savings to the public through low-cost transportation based on this estimate would be about $20,000,000 annually. With the 6-foot depth, the savings would be about half that amount.

Use of the Missouri River for traffic has been very limited to date, because the 6-foot project is just now approaching completion. During the calendar year 1940, about 52,000,000 ton-miles of traffic moved on the

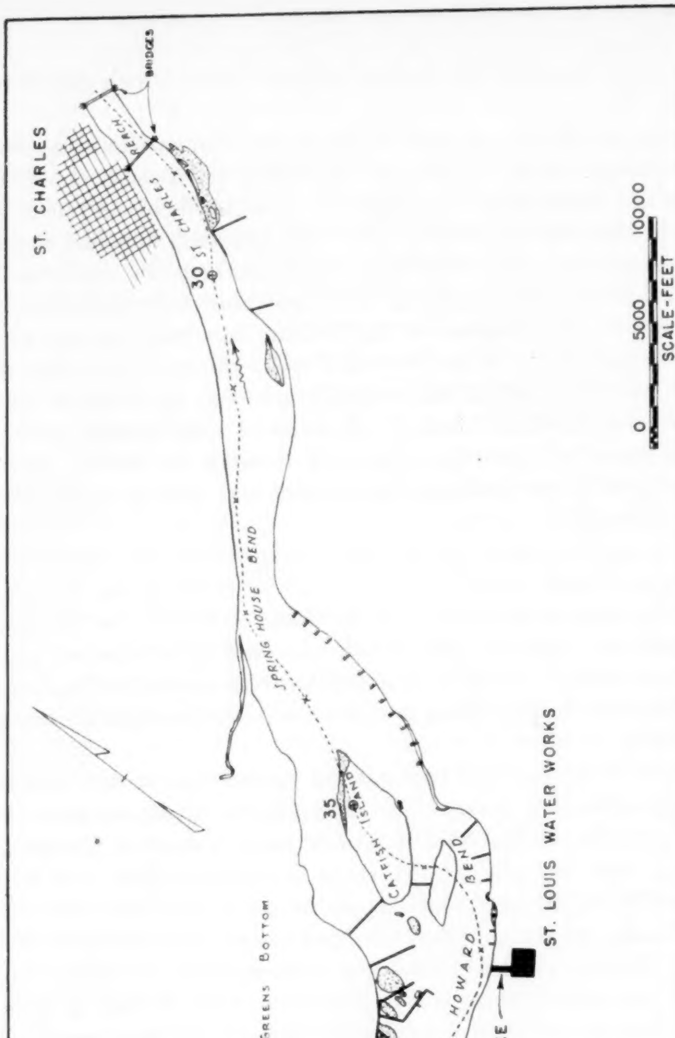

ST. CHARLES
BRIDGES
ST. CHARLES REACH
30
SPRING HOUSE BEND
35
CATFISH ISLAND
GREENS BOTTOM
HOWARD BEND
ST. LOUIS WATER WORKS
INTAKE
BONHOMME BEND
40
BONHOMME ISLAND
0
5000
10000
SCALE-FEET

FIG. 5A

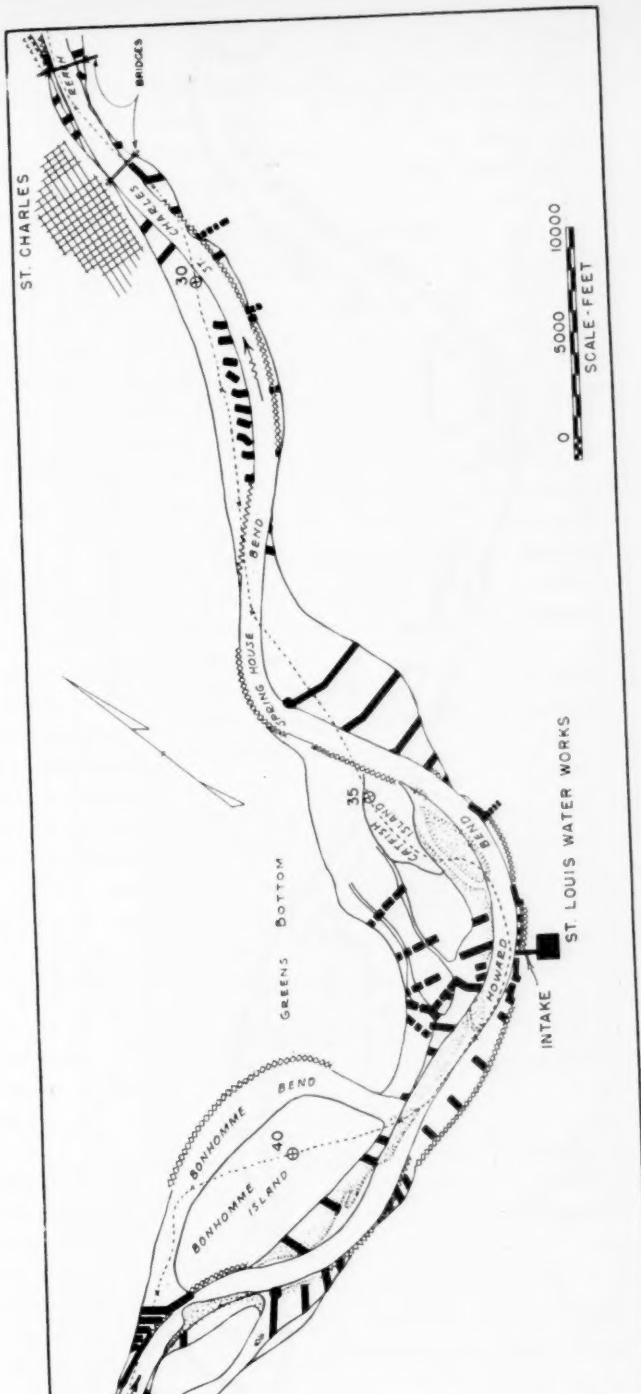

ST. CHARLES
BRIDGES
ST. CHARLES
30
SPRING HOUSE
BEND
35
CATFISH ISLAND
BEND
HOWARD
ST. LOUIS WATER WORKS
INTAKE
GREENS BOTTOM
BONHOMME BEND
40
BONHOMME ISLAND
0
5000
10000
SCALE - FEET

FIG. 5B

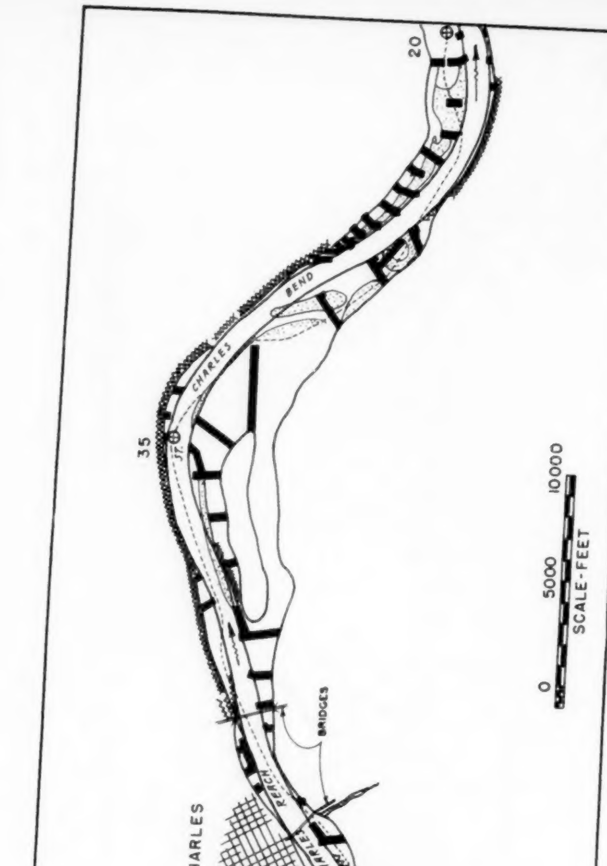

ST. CHARLES
ST. CHARLES WATER WORKS
INTAKE
BRIDGES
ST. CHARLES BEND
ST. CHARLES REACH
SPRING HOUSE BEND
20
30
35
0
5000
10000
SCALE-FEET

FIG. 6

river. It is estimated that 80,000,000 ton-miles moved during the calendar year 1941. Supplemental benefits will amount to $49,815,000 for agricultural land, $10,608,000 for reclaimed land, and $25,425,000 for utility benefits, a total of $85,848,000, or about half the cost of the 9-foot project.

Legal Considerations

The Constitution grants to Congress the power to regulate interstate commerce. While the Federal Government acquires from the Constitution no property rights in the shores and beds of water courses, nor in the water flowing therein, it does hold an easement for the benefit of commerce and navigation. This easement is dominant and controlling, and the rights of the states, or of riparian proprietors, are subordinate.

In dealing with an early question of damage, because of river-control structures, to a riparian owner, the Supreme Court said that the damage was not the result of the taking of any part of the property, whether upland or submerged, or a direct invasion thereof, but the incidental consequence of the lawful and proper exercise of a governmental power. In short, the damage was merely incidental to the exercise of a servitude to which the property had always been subject.

The substance of the veto message of the President in a recent case in which a public utility was damaged clarifies the situation. Necessary navigation improvements, it was said, are prosecuted in accordance with a long-settled principle that it is the duty of the Government to preserve and protect the navigability of our navigable waters, and that the cost of altering non-Federal structures that obstruct navigation shall be borne by the person, association, corporation or other body responsible for the structure, and not by the Federal Government.

To summarize, the Corps of Engineers has been ordered by Congress to make the Missouri River navigable for efficient transportation. While the work is done according to law, it is evident that in some instances it has conflicted with utility and private interests. On the whole, however, the benefits to those interests offset to a tremendous degree the damages suffered.

Discussion by *William T. Bailey*.* Colonel Besson has presented an excellent picture of the relationship of valley properties to the navigation control work along the Missouri River. He has shown that, in order to make the river navigable for efficient transportation, it has been necessary to stabilize it and to develop a satisfactory channel with a reasonable depth and an efficient alignment. He has demonstrated, too, that to accomplish a satisfactory job at a minimum cost, and, at the same time to

* Chemist, City Water Dept., Council Bluffs, Iowa.

protect, wherever practicable, industrial, commercial and agricultural interests, it has been necessary to make many compromises with the theory of design.

Perhaps the most important point to water works men, however, is the fact that, in some cases, fixed points were so located that no satisfactory compromise could be made. In such cases, as Colonel Besson pointed out, it is required by law that navigation be given priority rights over states, municipalities or private interests, despite the fact that those interests may be concerned with irrigation, power development or municipal water supply. Where the rights of riparian users are held to be subordinate to navigation and damage is done, it is held that, unless there is a direct invasion of property, the damage is the incidental consequence of the lawful and proper exercise of a governmental power and that affected parties are therefore not entitled to recover.

Under this interpretation of the law, then, water works may be subjected to large expenditures due to factors over which they have no control. If, for instance, the realignment of the channel diverts a river from an intake structure in such a manner that the structure is made useless, the owner is not entitled to damages, but must bear the full cost of relocation. Similarly, if the deepening of a channel, in the interest of navigation, creates such a condition that in extreme low water the pumps of an intake station would be so far above the water level that they would no longer lift water, or that the intake itself would be left completely above water, the ensuing damage is held to be consequential and the owner must bear the entire cost of relocation. Furthermore, parties so affected have been told that no notification is required in cases where navigation control work will inflict such consequential damage, but that it is the duty of riparian users, who may be subject to damage, to make inquiry as to what changes are being contemplated.

Status of Riparian Owners

Colonel Besson has pointed out that there are incidental benefits to valley properties in reclaimed land, prevention of erosion, the protection of bridges and other structures against a shifting stream, and in permitting water works intakes to be installed in permanent locations with the reasonable assurance of a reliable supply of water. There is, however, no assurance that an intake which must be moved, because of the diversion or deepening of a channel, will not have to be moved a second time if the navigation control solution used in that case proves unsuccessful. It is possible, therefore, under existing laws, for a riparian owner to suffer consequential damage repeatedly, each time being forced to rebuild at his own expense. There is also no assurance that there will be an ade-

quate flow of water at an intake in any given case, except the fact that the channel has been deepened and the bank stabilized.

Although this situation is created entirely within the law, it would seem only just that the readjustment costs, occasioned by such consequential damage to municipal and private interests as has been described, be considered part of the cost of the navigation control project and borne by the Federal Government. In other words, the decision to move an existing plant or to maintain a stream at its present location should be based on which method is actually the least expensive, with no thought to the question of saving Federal funds at the expense of riparian owners.

New River Decision

In the decision of the Supreme Court, rendered December 16, 1940 in the case of the *United States of America* v. *Appalachian Power Company*, it was held that a stream was navigable if, by the expenditure of a reasonable sum, it could be made navigable.* In a dissenting opinion, concurred in by Mr. Justice McReynolds, Mr. Justice Roberts said:

"... If this test be adopted, then every creek in every state of the Union which has enough water, when conserved by dams and locks or channelled by wing dams and sluices, to float a boat drawing two feet of water, may be pronounced navigable because, by the expenditure of some enormous sum, such a project would be possible of execution."

This being the case, practically every stream in the United States can be made subject to the navigation control laws of the Federal Government by a bill authorizing the development of navigation on them. Thus, when Congress passes a bill authorizing the development of navigation on any stream, all riparian users, whether states, municipalities or private individuals, may find their interests subordinated to the interests of navigation. They may then suffer consequential damages regardless of the length of time they have been established and without regard to whether the flow of the stream is being used for irrigation, power development, municipal water supply, or any other purpose.

---

*61 S.Ct. 291, 85 L.Ed. 201. Reproduced in full in the February 1941 JOURNAL (p. 315).

Ground Water in Southeastern Florida

By William P. Cross and S. Kenneth Love

THE rapid development of southeastern Florida has brought about important problems concerning the use and control of the water resources of the region. Perhaps the most important water problem is that of public supply. In an effort to obtain the basic data necessary to the comprehensive study of the water problems of the area, the U.S. Geological Survey began, in the fall of 1939, a water resources survey in co-operation with Dade County and the cities of Miami, Miami Beach, and Coral Gables. The ground water investigation, which is part of the survey being conducted by the Ground Water, Surface Water, and Quality of Water Divisions of the Geological Survey, has been concentrated largely in Dade County.

The purpose of the ground water investigation is to make available detailed information on the source of underground waters, their movement through permeable strata, their quality, quantity, losses, sustained yield, and the magnitude and velocity of salt water intrusion.

Information concerning the water resources and the water-bearing formations in southeastern Florida is contained in several reports. Matson and Sanford (1), in 1913, prepared a most comprehensive report on the ground water of the entire state, but it contains little detailed information on southeastern Florida. In 1928, Collins and Howard (2) reported on the quality of ground water. A year later, the most comprehensive description of the geology of the state was published in a report by Cooke and Mossom (3). In two reports dated 1933 and 1936, Stringfield (4, 5) described briefly the water-bearing formations and ground water in the area adjacent to Lake Okeechobee and artesian water in southern Florida. And, in March 1941, the U.S. Geological Survey staff prepared a progress report (6) on the present water resources investigation.

It is estimated that there are more than 10,000 wells in Dade County, ranging in depth from a few to 120 ft. or more. The ease with which

A paper presented on November 13, 1941, at the Florida Section Meeting, Daytona Beach, Fla., by William P. Cross, Assoc. Engr., and S. Kenneth Love, Assoc. Chemist, Geological Survey, U.S. Dept. of the Interior, Washington, D.C. Published by permission of the Director, Geological Survey, Dept. of the Interior.

shallow wells of large capacity may be drilled has resulted in the use of ground water for practically all domestic, public and industrial water supplies. Ground water is also used for irrigation in some parts of the area, and wells are used for storm water drainage and the disposal of laundry and other wastes. There are more than 350 "fire" wells in Dade County drilled to supply water for fire protection in areas inadequately served with water mains.

Climate

Southeastern Florida has a semi-tropical climate. U.S. Weather Bureau records show the average temperature at Miami during 42 years of record to be about 76°F., with a maximum of 96°F. and a minimum of 27°F. The mean annual precipitation at Miami, for 33 years of record, is 58.8 in. The Everglades area is somewhat warmer in summer and cooler in winter, and available records indicate slightly less rainfall than at Miami; but the Miami weather records are generally representative of southeastern Florida. Climatic conditions are such that evaporation and transpiration losses are large throughout the year.

Topography and Drainage

The greater part of the interior of southern Florida is included in the great sawgrass swamp of the Everglades that forms a nearly level plain sloping from an altitude of about 18 ft. above sea-level near Lake Okeechobee to sea-level in the mangrove covered keys in Florida Bay. Lake Okeechobee, the second largest fresh water lake in the United States, is a very shallow body of water lying within the north margin of the Everglades. East of the Everglades is the coastal area of slightly higher ground. In Dade County this is a low limestone ridge which follows the coast line and gradually decreases from a height of not more than 30 ft. at Miami to sea-level at Florida Bay.

Lake Okeechobee drains an area of about 5,500 sq.mi. of prairie and sandy pine land to the north, principally through the Kissimmee River and Fisheating Creek. Prior to artificial drainage operations, Lake Okeechobee often overflowed into the Everglades to the south, and much of the area was flooded at all times, but now part of the excess surface waters are drawn off through the canals and normal water levels have been lowered, especially near the canals themselves. The Caloosahatchee River and St. Lucie Canal are the principal outlets of Lake Okeechobee, but the Palm Beach, Hillsboro, and North New River Canals also extend from the lake to the ocean and carry some of the outflow. These canals, together with the South New River, Miami, Tamiami, and many other shorter canals

and natural water courses, drain the coastal area and, to some extent, the Everglades (see Fig. 1).

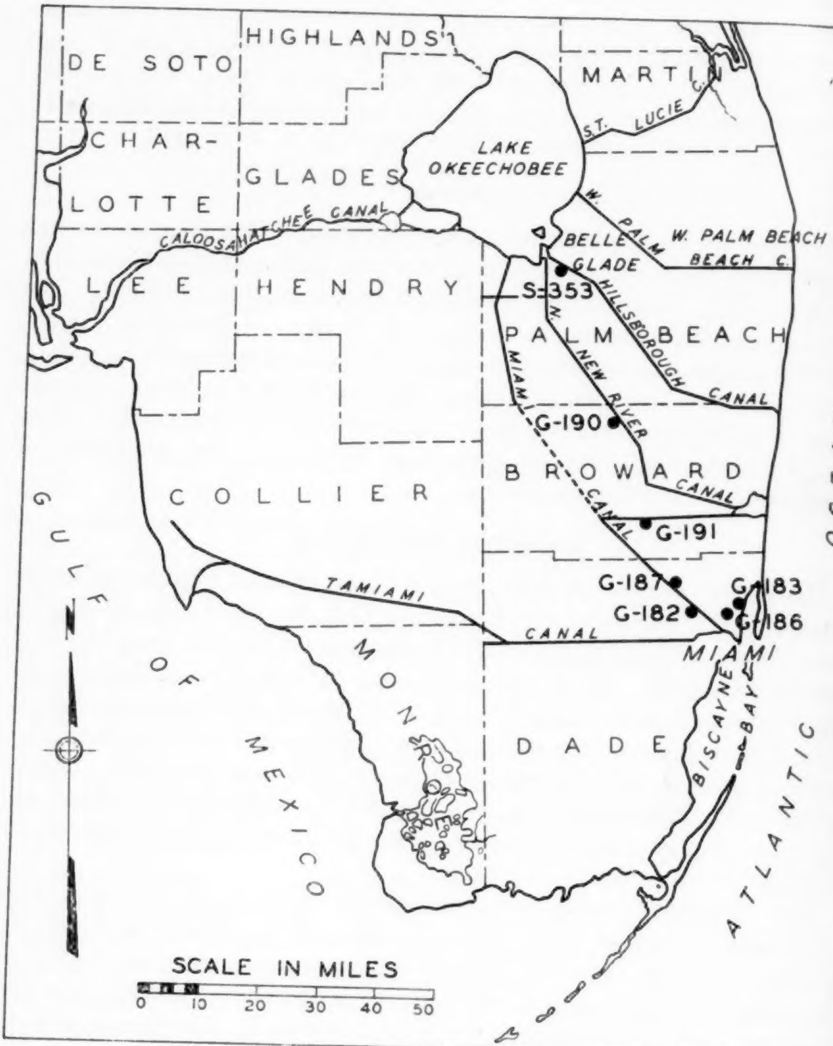


FIG. 1. Location of Principal Canals and 7 Test Wells in Southeastern Florida

During periods of prolonged rainfall the flow in the upper reaches of some of the canals reverses in direction and a portion of the flood water in the Everglades drains into Lake Okeechobee. Many canals in Dade County are not controlled by dams or any other means, but are open water-

ways connected directly or indirectly with Biscayne Bay. The excessive drainage brought about by these uncontrolled canals has been a major factor not only in the subsidence and burning of large areas of muck in the Everglades, but also in the salt water contamination of the surface and ground waters near the coast.

Water-Bearing Formations

The surficial formations in southeastern Florida are oölitic limestone and unconsolidated sand, muck and marl. Directly underlying these are beds of sandy limestone, calcareous sandstone and sand which are exceedingly permeable and yield very large supplies of water to wells. In the coastal area these productive water-bearing formations generally extend to depths of about 120 ft. and in limited areas long Biscayne Bay, to about 300 ft. They thin out and are less productive under the Everglades to the west. Below these rocks, to a depth of about 500 ft., lie beds of clayey marl, limestone and other relatively impermeable materials which yield little or no water but act as confining beds for the artesian water in the underlying Tampa, Ocala and associated limestones. In northern and central Florida, the Tampa and Ocala limestones yield large quantities of water of satisfactory quality, but in southeastern Florida these formations are less productive and their water is too highly mineralized for most uses.

Because of the unsatisfactory quality of the deep artesian water, the investigation has been concerned for the most part only with the shallow formations. Practically all of the many wells in the area are in the highly permeable rocks immediately below the surficial formations. Figure 2 is a generalized geologic cross-section from Lake Okeechobee to Miami prepared by G. G. Parker of the U.S.G.S. from information obtained from the test wells indicated in Fig. 1. The stratigraphy shown is tentative and subject to revision.

Methods of Investigation

The large number of existing wells simplified the water level observation program, so that only in the more remote parts of the area was it necessary to install observation wells. Levels were run to several hundred selected wells, and readings of the water levels in about 200 wells have been made on a weekly or bi-weekly schedule since the beginning of the investigation. Water levels were also observed in the canals, rock pits, and quarries. Twenty-four key wells were equipped with water stage recorders which give a graphic record of the fluctuations of the water levels. From these records, hydrographs have been prepared and studied in conjunction with weather records, and water table contour maps have been prepared for

critical periods. Figures 3 and 6 include water table maps of areas in the vicinity of Miami. Contours crossing the canals are not shown, as the canals are tidal and sufficient data are not available to determine the mean water levels. In the maps in Fig. 6 the Miami Canal is effluent, the mean water level being approximately 6 in. above the water table nearby. Contours closing along the canal bank as well as contours crossing the canal are omitted.

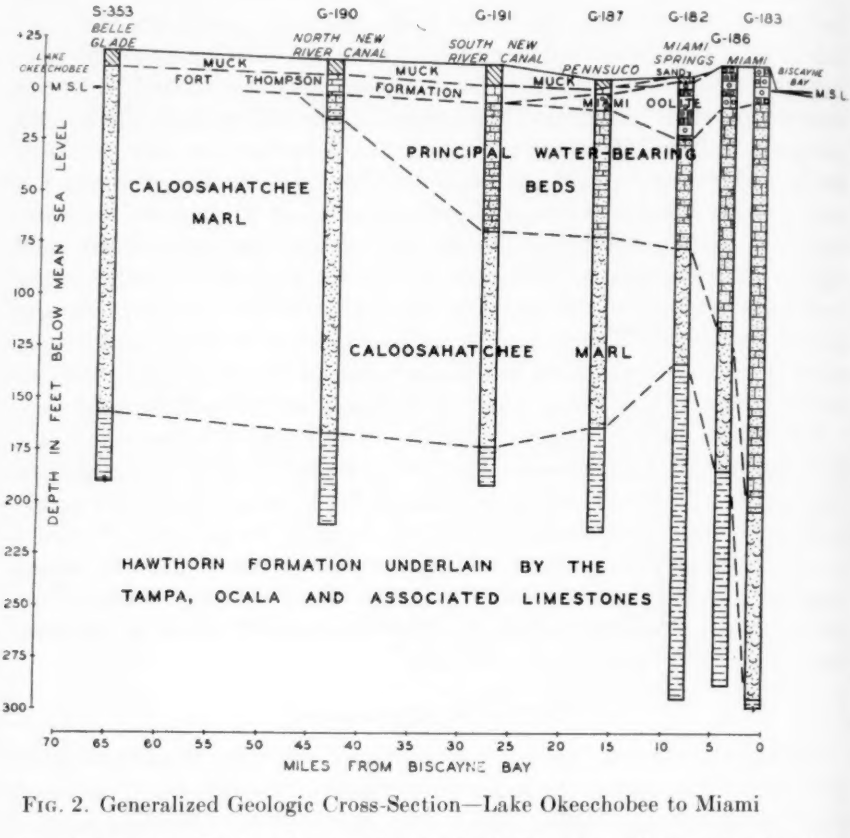


FIG. 2. Generalized Geologic Cross-Section—Lake Okeechobee to Miami

To determine the location and extent of the permeable water-bearing formations and the quality and quantity of ground water in the formations, as well as to extend the detailed knowledge of the geology of the area, about 20 test wells were drilled, under the close supervision of geologists. Samples of the water encountered and of the drill cuttings were taken carefully, the water samples analyzed and the rock samples studied. These wells were drilled to depths sufficient to penetrate the top of the relatively

impermeable formations. Through the co-operation of several public agencies, well drillers and individuals, rock and water samples have been obtained from many other wells. This has made possible detailed studies of the geologic formations, of the hydrologic characteristics of these rocks, and of the quality of the water found in the water-bearing formations.

The surface and ground waters of the area are closely interrelated and the work of the Surface Water Division of the U.S.G.S. was co-ordinated with that of the Ground Water Division. Studies were made of the rate of inflow into the canals in conjunction with water table contour maps of the tributary areas, and from these records the permeabilities of the water-bearing materials were computed. Determinations of permeabilities were also made by means of pumping tests on wells, by studies of the pumpage from, and water levels in, the Miami water supply well field, and by laboratory studies of unconsolidated materials taken during the drilling of test wells.

Shallow Ground Water

The maps of the water table show that the ground water moves in general in an easterly or southeasterly direction, from the Everglades toward the sea, with a very low gradient. The network of canals has a pronounced effect, however, on the direction of movement, and the relatively high gradients toward the canals in most places indicate that a large part of the ground water reaches the sea by way of the canals. At some places the ground water moves from the relatively high coastal area toward the Everglades, and in some places it flows away from the canals rather than toward them. Water table contour maps of the Miami area for water levels during a low, medium and high water period are shown in Fig. 3.

Although some of the ground water in the coastal area is received as a result of the slow eastward or southeastward percolation, a very large proportion is derived from the rain that falls directly on this area. The available data indicate that about 40 to 50 per cent of the rainfall on the coastal area reaches the water table. The discharge of ground water takes place chiefly through the canals and by evaporation and transpiration. Although a large quantity of water is pumped from wells, this quantity constitutes only a small part of the total ground water discharge.

The studies of the permeability of the principal water-bearing beds show them to be among the most productive that have been investigated by the U.S.G.S. All information obtained points to the conclusion that very large quantities of ground water are available for use in the coastal area. Because of the uncontrolled canals, however, large areas along the coast are subject to contamination by salt water intrusion.

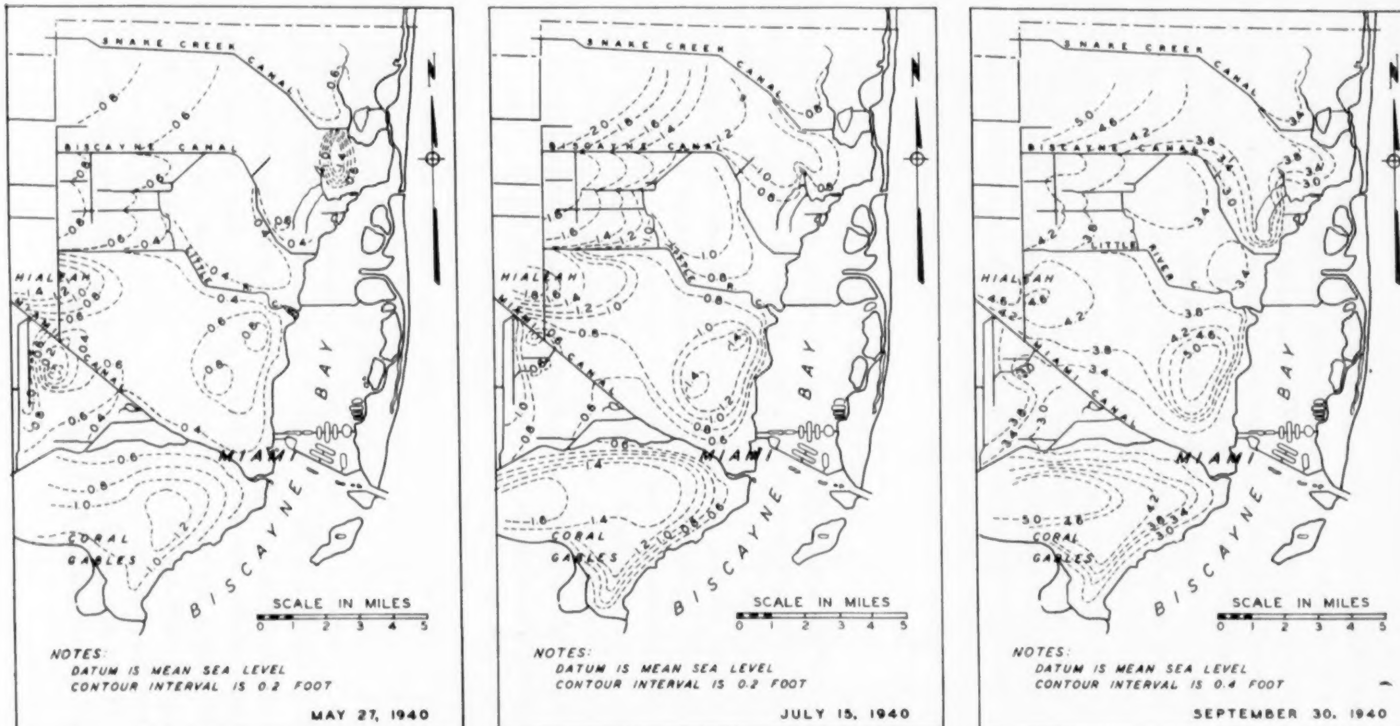


FIG. 3. Water Table Contours in the Miami Area

Quality of Water

The large number of wells of various depths scattered over the area facilitated the investigation of the quality of ground water. Over 5,000 samples of well water have been collected and analyzed in the U.S.G.S. laboratory established in the Dade County Court House. Determinations of the chloride content and the specific conductance were made on all samples. The principal constituents were determined on samples collected from selected wells and complete analyses were made of a few samples. This work was supplemented by analyses made in the Water Resources Laboratory in Washington. Use was also made of published and unpublished analyses furnished by officials of the cities of Miami and Miami Beach.

The composition of uncontaminated ground water is fairly uniform in the coastal area in and near Miami. The concentration of total dissolved solids ranges from about 250 to 300 ppm. and the total hardness, expressed as calcium carbonate, ranges from about 225 to 275 ppm. Dissolved mineral matter consists largely of calcium and bicarbonate. Objectionable amounts of iron are found in some wells but the concentration appears to bear little or no relation to location or depth. Practically all of the shallow ground water is colored by organic matter. Color is usually between 40 and 80 on the standard color scale, but in some wells is less than 5 and in others more than 100.

The composition of a typical ground water is represented graphically in Fig. 4 by an analysis of water from well S-7, and the composition of a typical ground water contaminated with salt water is represented by an analysis of water from well S-4. Both of these wells are located in the Hialeah-Miami Springs well field, from which the Miami public supply is obtained. The analysis of the treated water from this well field represents a mixture of water from several of the wells, including some that were contaminated with salt water at the time the sample was collected. Analyses of both raw and treated water from the Coconut Grove plant represent ground water contaminated with salt water. Because of this contamination, operation of the Coconut Grove Plant was discontinued during the summer of 1941 and the area formerly served by this plant is now supplied with water from the Hialeah plant.

The analyses of surface water, which are included in Fig. 4 for comparison with analyses of ground water, indicate that water in the Kissimmee River is very soft and low in dissolved mineral matter and that water in Lake Okeechobee, although more concentrated than in the river, is softer and contains less dissolved matter than ground water in the Miami area. The composition of uncontaminated surface water in canals in and near

Miami is, in general, similar to that of ground water except that the sulfate content is appreciably less. The average hardness and the total concentration of dissolved solids in surface water is usually a little lower than that of ground water, but the color, which varies considerably, is usually much higher than the color of ground water.

The chemical character of shallow ground water in uncontaminated wells near the coast in Broward and Palm Beach Counties is, in general, similar to, but a little less concentrated than, shallow ground water in the metropolitan area of Miami. Chloride concentrations in Palm Beach

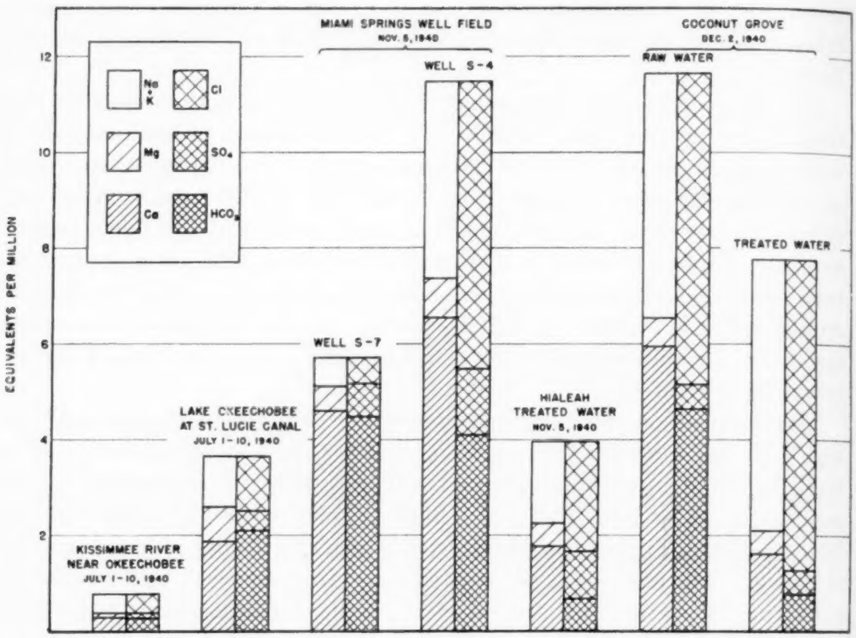


FIG. 4. Analyses of Surface and Ground Waters in Southeastern Florida

County are, on the average, a little higher than in the coastal areas of Dade County. Analyses of samples collected from public supply wells in Riviera, Lake Worth, Pompano and Deerfield Beach show that these waters are somewhat less concentrated and less hard than water in public supply wells in Miami.

Analyses of ground water in the Lake Okeechobee area made in 1933 have been supplemented by analyses made during the present investigation and show that both shallow and deep ground waters from wells near the lake contain large amounts of dissolved mineral matter. Hardness ranges from about 250 to over 900 ppm., sulfate from about 200 to 600 ppm., and

chloride from less than 100 to over 2,000 ppm. The high concentration of dissolved mineral matter in the ground water has been largely responsible for the utilization of water from Lake Okeechobee for nearly all of the public supplies of the towns near the lake.

Salt Water Intrusion

In a belt as much as two miles wide along the coast of Biscayne Bay in the Miami area, and several miles farther inland along the Miami Canal, the ground water above the confining beds contains more chloride than the normal ground water in the region. High chloride concentrations in wells near the bay, which diminish inland, except along the canals, and absence of chloride in excess of about 25 ppm. for several miles farther inland in the vicinity of Miami, show that salt water from the ocean is the source of contamination. Intrusion of salt water appears to have taken place both by direct penetration of the water bearing formation by sea water along the shore of Biscayne Bay and the navigable channel of the Miami River and canal, and by downward percolation of salt water from the canals at times when low ground water levels and low flow in the canals permitted movement of sea water several miles inland.

An indication of the extent to which ground water in the Miami area has been contaminated by salt water may be obtained by the comparison of past and present records of chemical analyses. Isochlor maps have been prepared showing chloride concentrations at different depths, based on the results of chloride determinations. Key wells are sampled periodically and the chloride concentrations in the Miami water supply well field have been studied in considerable detail. The results from the periodic sampling of key wells during the investigation have shown no appreciable changes in chloride concentrations except in a few isolated locations. Comparison of the results of the general sampling of the entire area in 1940, with results from a fairly general sampling of part of the Miami area in 1928–29, indicates that the chloride content of water at a depth of about 100 ft. in 1940 was about the same as in 1928–29, except where the tidal canals have brought sea water some distance inland, contaminating narrow zones on both sides of the canals. Samples were not taken from wells less than 75 ft. deep in 1928–29, so no comparison can be made for the shallow wells. It seems probable, however, that these wells would show even smaller differences than the deeper wells. This comparison, together with the results from a few wells in 1924 and the insignificant changes in chloride concentrations in the past two years, strongly suggests that no great changes in concentration have taken place for many years, except where canals or other drainage operations have upset the salt water-fresh water

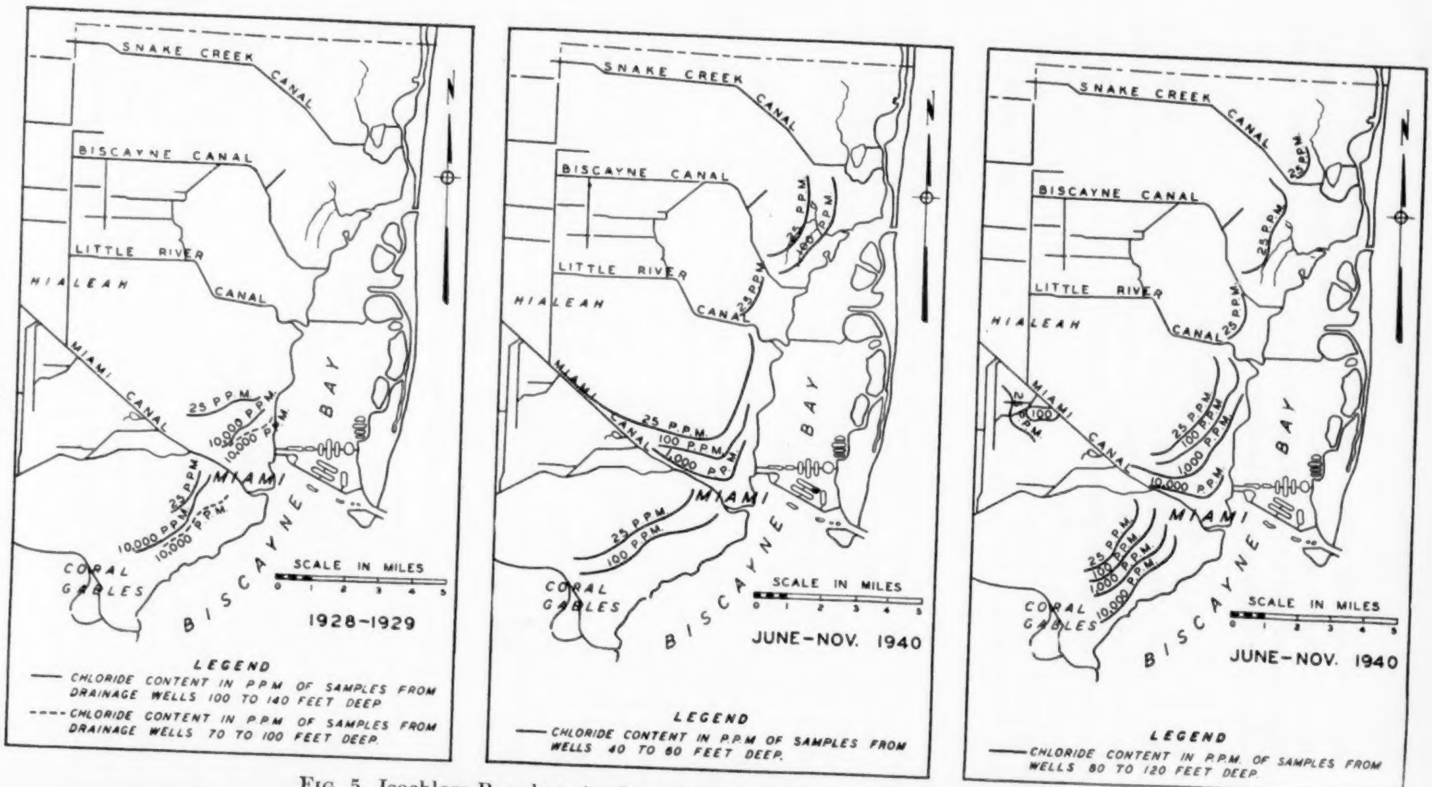


FIG. 5. Isochlors Based on Analyses of Well Water Samples in the Miami Area

balance. Despite the low ground water levels, the zone of salt water contamination is not extensive along the coast and does not appear to be increasing in area or concentration. Isochlor maps of the Miami area are shown in Fig. 5.

Contamination of the ground water formations through the uncontrolled canals may occur in two ways. At times of high tide and low ground water levels, large volumes of sea water may flow up the channels of the canals, contaminating large areas at considerable distances from the ocean by lateral and downward percolation into the water-bearing formations. Such a condition occurred in the Miami Canal in the spring of 1939, and caused several of the Miami water supply wells to become brackish. In Fig. 6 are isochlor maps of the Miami water supply well field showing developments following this intrusion, together with water table contour maps for the same period.

The other type of contamination is identical with the wedge-shaped intrusion at depths extending inland from the shore line of the ocean, as the deep canals are essentially arms of the sea. Low canal levels disturb the salt water-fresh water equilibrium in the water-bearing beds under the canal, so that the heavier sea water moves laterally beneath the fresh water, extending the contamination farther inland. The first type of intrusion can be prevented by the installation of dams in the canals, without materially raising water levels. Prevention of the second type requires more adequate control of water levels and the operation of dams or control works for longer periods.

The intrusion which caused the public supply wells near the banks of the Miami Canal in Hialeah to become brackish almost immediately after the canal became salty, as shown in Fig. 6, was clearly of the first type. The results of analyses of water samples from test wells near the eight public supply wells in the Miami Springs golf course (near the bottom of the map) show that the slower moving contamination in this area also was of the first type, because the chlorides did not increase in concentration with depth, as would be the case in the second type. It would appear that the salt water entered the small lake east of the well field at high tide, became trapped, and moved slowly down gradient toward the center of the cone of depression caused by heavy pumping in the well field.

Salt water intrusion of the second type has resulted in contamination of the deeper formations along the Miami Canal. A zone of salt water, in which chloride concentrations as high as 4,000 ppm. have been found at depths of from 70 to 90 ft., now centers around the head of the navigable channel in the Miami Canal near N.W. 36th Street, about two miles downstream from the Miami water supply well field. This deeper intrusion

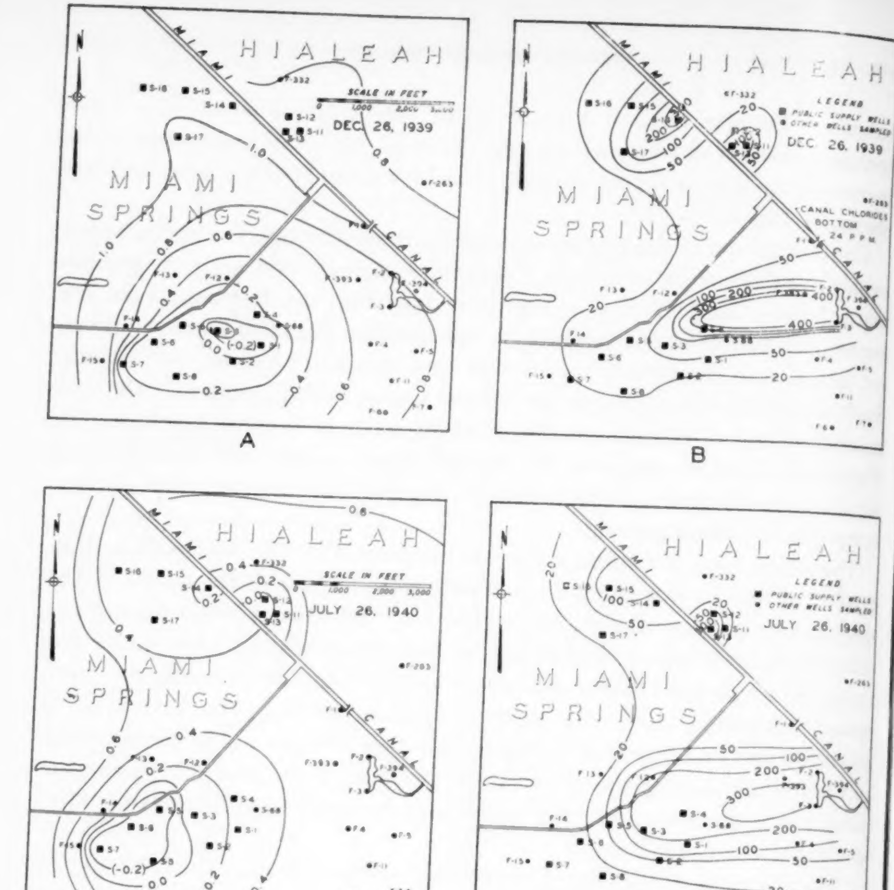


FIG. 6. Hialeah-Miami Springs Well Field; showing (*A*, *C*, *E*) Water Table Contours, in feet referred to mean sea-level, and (*B*, *D*, *F*) Isochlors, in ppm.

apparently has been progressing inland along the Miami Canal during dry periods since deepening of the canal in 1931–32, and presumably will continue to move inland unless water levels in the canal are controlled during dry periods. Unless remedial measures are taken in the near future it seems probable that salt water contamination resulting from the deeper type of intrusion, as well as that which takes place through the action of the tides in the canal, will in time encroach upon the present well field to such an extent that partial or complete abandonment may become necessary.

Consideration has been given to the possibility of utilizing surface water in the Miami Canal to supplement the present public supply for the metropolitan area of Miami. This plan is also dependent in part upon adequate control of water levels in the canal and in part upon the development of a larger flow during dry periods.

Analyses of water samples collected from test wells in the vicinity of the North New River Canal and the incomplete portion of the Miami Canal from the South New River Canal to Lake Okeechobee indicate that an area of highly mineralized ground water may extend over a large part of the central and northern Everglades. Inasmuch as ground water along the coastal ridge in Dade, Broward, and Palm Beach Counties is in general similar in composition to the uncontaminated shallow ground water in and near Miami, it is probable that the high mineral content of ground water in the Everglades is not the result of salt water intrusion from the ocean in recent geologic times. It has been suggested that the mineralization in this area may largely be the result of invasions by the sea into old Lake Okeechobee in Pleistocene times. The highly mineralized ground waters in the vicinity of Lake Okeechobee may also be the result of such invasions of the sea.

Ground Water as a Future Source of Supply

Analysis of the detailed records collected during the intensive investigation of the ground water resources in southeastern Florida leads to the conclusion that large quantities of ground water are available for the development of public water supplies along the coastal area, particularly in the metropolitan area of Miami. The critical problem in connection with future development is largely one of salt water intrusion. The chemical character of the shallow ground water is suitable for public supply but it is endangered by contamination with salt water from tidal canals. By controlling the water levels in the canals to prevent not only the intrusion of salt water from the canals themselves, but also the contamination by percolation of salt water through the water bearing formations in the vicinity of the canals, it is believed that supplies of uncontaminated ground water adequate for the future needs of the metropolitan area of Miami can

be developed. The possibility of salt water contamination will be further reduced by locating new wells as far as practicable from possible sources of contamination and by spreading them over a considerable area.

References

1. Matson, G. C. and Sanford, Samuel. Geology and Ground Waters of Florida. U. S. Geol. Survey, Water Supply Paper 319 (1913).
2. Collins, W. D. and Howard C. S. Chemical Character of Waters of Florida. U. S. Geol. Survey, Water Supply Paper 596-G (1928). pp. 177–233.
3. Cooke, C. W. and Mossom, Stuart. Geology of Florida. Florida Geol. Survey, 20th Ann. Rept. (1929). pp. 29–228.
4. Stringfield, V. T. Ground Water in the Lake Okeechobee Area, Florida. Florida State Board Conservation, Geol. Dept., Rept. 2 (1933).
5. ———. Artesian Water in the Florida Peninsula. U.S. Geol. Survey, Water Supply Paper 773-C (1936).
6. Cross, W. P., Love, S. K., Parker, G. G. and Wallace, D. S. Water Resources of Southeastern Florida. Mimeographed report and memorandum for the press (March 29, 1941).

Chemical Character of the Larger Public Water Supplies in Georgia

By William L. Lamar

TO OBTAIN information necessary for planned industrial progress in Georgia, a study of the chemical character of the larger public water supplies of the state was undertaken by the U.S. Geological Survey in co-operation with the Georgia Division of Mines, Mining, and Geology and the Georgia Department of Public Health. This investigation included 66 of the larger public water supplies serving a total population of 1,098,819, or 35 per cent of the population of the state. The surface supplies serve 759,784 consumers and the ground supplies, 339,035. Detailed results are presented in U.S. Geological Survey Water Supply Paper No. 912, which is now in process of publication.

The investigation was made possible through the co-operation of Capt. Garland Peyton, Director, Georgia Div. of Mines, Mining, and Geology and W. H. Weir, Assoc. Director of Public Health Eng., Georgia Dept. of Public Health. The work was under the direction of W. D. Collins, Chemist in Charge, Quality of Water Div., U.S. Geological Survey.

All cities in Georgia having a population of 2,500 or more at the time of the 1930 census were included in the study. The population figures used, however, are those of the 1940 census. The 66 public water supplies considered were visited by the writer and the information was obtained directly from the water works officials, samples being collected and sent to the water resources laboratory of the geological survey, at Washington, for analysis. When treatment, other than chlorination and aeration, was applied to the water, samples were collected and analyses made of the raw and finished water.

The State of Georgia has two major physiographic regions—the Appalachian Highlands which lie to the north and the Coastal Plain, to the south of an irregular line passing through the cities of Augusta, Macon, and Columbus.

A contribution by William L. Lamar, Assoc. Chemist, Geological Survey, U.S. Dept. of the Interior, Washington, D.C. Published by permission of the Director, Geological Survey, Dept. of the Interior.

The Appalachian Highlands in Georgia include four provinces: the Piedmont, the Blue Ridge, the Valley and Ridge, and the Cumberland Plateau. The elevations range from about 400 ft. above sea-level near the fall-line to more than 4,000 ft. in the mountains. In general, this region is underlain with igneous and metamorphic rocks. In the northwestern part of the state the formations consist largely of limestone, dolomite, sandstone, shale, and quartzite. Numerous springs and wells which furnish small quantities of water are to be found in the region. Also, a relatively small number of wells penetrating sandstone and limestone formations yield large quantities of water; and a few springs yield considerable quantities of water. On the whole, however, the wells and springs do not yield sufficient water to supply the larger cities. The public supplies of this region which are covered by the survey include five places which obtain from about 20 to 100 per cent of their supply from springs, and six which obtain from about 12 to 100 per cent of their supply from wells. The wells used by these places generally yield less than 100 gpm. Including the cities at the fall-line, 32 of the 33 surface supplies considered are in the Appalachian Highlands. The surface supply at Cartersville is supplemented with some spring water and that at La Grange with some well water.

The Coastal Plain includes about three-fifths of the total area of the state. On the whole, this region comprises hilly and broken sections in the northern part and rolling land merging into flat, sandy country toward the coast. This province is underlain with sedimentary rocks containing water-bearing strata in sand, gravel, and limestone. It is a productive area of artesian water and large quantities have been developed for public and industrial supplies. Of the public supplies listed, 26 are in the Coastal Plain, and of this number, 25 obtain their supply from artesian wells. Americus supplements its well supply with water from springs.

Chemical Character of Georgia Waters

The general character of the water furnished by the larger public water supplies in Georgia is indicated by the data obtained from a study of 157 complete mineral analyses. The mineral content of a few of the surface waters may occasionally exceed the ranges in concentration given, and changes in ground water supplies may alter to some extent the chemical composition of these supplies, but the data given may be considered to represent reasonably well the composition of the larger public water supplies in Georgia.

Surface Water

The mineral content of the surface waters will vary from time to time due to the variations in the constituents naturally present and to the variations

in the treatment of the water. In all but a few of the surface supplies, however, the mineral content is below 100 ppm. at all times.

Silica (SiO_2) ranged from about 5 to 30 ppm., with an average of about 12 ppm. The raw waters contained very little iron and most of the small amount originally present was removed by treatment. Coagulation and filtration leave the water in such a condition that it can and does dissolve iron from pipes unless some final treatment is applied to prevent corrosion. With the exception of several supplies in the northwestern part of the state, the calcium content of the raw water was below 10 ppm., and generally below 5 ppm. Magnesium content was lower than calcium. Lime, when used to aid coagulation and particularly when used in the final adjustment of pH, increases the calcium content of the finished waters. Sodium and potassium together were below 10 ppm. for the raw waters. Soda ash (sodium carbonate) used in treatment at a few places increases the sodium content of the finished water.

Bicarbonate is the principal acid radicle of the surface waters. The use of alum (aluminum sulfate) as a coagulant reduces the bicarbonate and increases the sulfate, but frequently the bicarbonate is brought back or even increased by the final adjustment of the pH. Sulfate content for the raw waters was below 10 ppm., and generally below 5 ppm.; for the finished waters it ranged from 5.2 to 34 ppm. Chloride was quite low, usually below 5 ppm. The analyses do not show more than 0.2 ppm. fluoride, and nitrate was usually below 1 ppm. A few analyses show a nitrate content between 1 and 2 ppm. and occasionally, in some of the waters, it exceeded 2 ppm.

Ground Water

A single analysis is usually representative of the composition of the water from an artesian well throughout the year. The composition of the mixed water from several artesian wells will depend on the mineral content of the individual wells and on the extent to which each well is used. The mineral content of the ground supplies covers a wide range, the extremes being 19 and 1,030 ppm. For the majority of the ground supplies, however, the mineral content is between 100 and 200 ppm.

Silica ranged from about 5 to 60 ppm. With few exceptions, the artesian well supplies in the Coastal Plain are free from objectionable quantities of iron. Some of the wells in the Appalachian Highlands are more likely to contain enough iron to cause trouble. The hard artesian well waters are generally not corrosive, but the hydrogen sulfide present in a number of the artesian waters in the southern part of the state causes some corrosion. The analyses show a minimum calcium of 1.1 ppm. for one well and for a group of springs, both of which are in the Coastal Plain. For the

TABLE 1

*Hardness of 66 of the Large Public Water Supplies in Georgia**

Surface Supplies: Place	Population Served	Hardness as $CaCO_3$ in ppm.: Raw Water	Finished Water	Ground Supplies: Place	Population Served	Hardness as $CaCO_3$ in ppm.: Raw Water	Finished Water
Athens	20,650	15	32	Albany	19,055	81	81
Atlanta	342,300	11	22	Americus	9,281	95	95
Augusta	65,919	16	18	Bainbridge	6,352	121	121
Barnesville	3,535	9.8	26	Brunswick	15,035	205	205
Buford	4,191	15	42	Cairo	4,653	621	621
Canton	3,000	12	23	Cartersville†	6,141	117	41
Carrollton	6,214	13	34	Cedartown	9,025	132	132
Cartersville†	6,141	15	41	College Park	8,213	44	55
Columbus	56,000	12	23	Cordele	7,929	123	123
Commerce	3,294	8.3	9.8	Cuthbert	3,447	138	138
Covington	4,800	9.4	11	Dawson	3,681	118	118
Dalton	10,448	131	60	Douglas	5,175	198	198
Decatur	17,100	16	30	Dublin	7,814	178	45
East Thomaston	3,590	12	12	Eastman	3,311	136	136
Elberton	6,600	9.6	32	East Point	12,403	110	120
Gainesville	11,200	6.9	16	Fitzgerald	7,388	94	94
Griffin	13,222	20	32	Fort Valley	4,953	5.2	12
La Grange§	21,983	20	32	Hapeville‡	5,059	58	58
Macon	67,900	16	28	Lafayette	3,700	86	86
Manchester	3,462	2.6	24	La Grange§	21,983	93	93
Milledgeville:				Lindale	3,361	146	146
Municipal	8,700	33	44	Marietta	8,667	60	60
State Hospital	8,000	18	20	Millen	2,820	113	113
Monroe	4,168	8.9	17	Moultrie	10,147	113	113
Newnan	7,182	9.2	21	Pelham	2,579	166	166
Porterdale	3,116	13	15	Quitman	4,450	141	141
Rockmart	3,764	66	63	Sandersville	3,566	49	49
Rome	26,282	39	50	Savannah	100,000	106	106
Rossville	3,538	64	72	Statesboro	5,028	106	106
Silvertown	3,930	12	12	Thomasville	12,683	202	60
Thomaston	6,396	12	11	Tifton	5,228	144	144
Toccoa	5,494	8	16	Trion	3,800	103	103
Washington	3,537	31	33	Valdosta	15,595	98	98
Waynesboro	3,793	16	32	Vidalia	4,109	102	102
Winder	4,100	6.2	37	Waycross	16,763	148	148
Average		21	29			131	123
Weighted Average		16	25			122	115

* Total population served, 1,098,819.

† The finished water is a mixture of about 80 per cent river water and 20 per cent spring water.

‡ A small amount of finished surface water is purchased from Atlanta.

§ A small proportion of the consumers receive well water or a mixture of well and river water.

water delivered to consumers, the calcium ranged from about 4 to 132 ppm. Again magnesium content was lower than calcium. A few of the well waters containing considerable calcium had only small amounts of magnesium. The sum of the sodium and potassium was less than 20 ppm. in all but a few of the supplies. The maximum sodium found in the most highly mineralized water was 69 ppm. and the maximum potassium 5.6 ppm.

Bicarbonate is the principal acid radicle of the ground waters considered, except for a few well supplies that contained appreciable quantities of sulfate; the sulfate, however, was generally below 20 ppm. In the southern and southeastern parts of the Coastal Plain the sulfate was higher, reaching a maximum of 522 ppm. at Cairo. Some of the well waters in the Appalachian Highlands contained appreciable sulfate. At East Point the sulfate content of well No. 5 was 239 ppm. The chloride content of the waters was generally below 5 ppm. In only one supply, that of Cairo, did the chloride content exceed 20 ppm. (75 ppm.). None of the underground waters analyzed during this investigation contained more than 0.5 ppm. of fluoride. Only three of the artesian well waters in the Coastal Plain had more than 2 ppm. of nitrate. Some of the well waters in the Appalachian Highlands had higher nitrate contents, with a maximum of 28 ppm. for well No. 18 at Marietta. The nitrate content of the spring waters ranged from 2.2 to 10 ppm.

Carbonate hardness caused by calcium and magnesium bicarbonates represents much of the mineral content of the waters. In the coagulation of the surface waters the sulfate is increased at the expense of the bicarbonate, but generally the bicarbonate is brought back or even increased by the addition of lime or, occasionally, soda ash. If lime is used, the hardness of the water is increased. Some of the underground waters contain very little besides silica, calcium, magnesium, and bicarbonate. A number of the artesian well waters in the southern and southeastern parts of the Coastal Plain have some non-carbonate hardness due to the presence of calcium sulfate so that the hardness of these waters is increased accordingly. The surface streams, with little exception, furnish soft water; the hardest surface supplies considered are in the northwestern part of the state. The ground supplies cover a wide range in hardness, but most of them may be considered moderately hard to hard.

The hardness of the surface waters ranged from about 3 to 131 ppm. for the raw water and from about 10 to 72 ppm. for the finished water. The extremes in hardness of the underground supplies in the Coastal Plain were 5.2 ppm. for raw water and 12 ppm. for finished water at Fort Valley and 621 ppm. at Cairo. The waters from the individual wells in the Appalachian Highlands ranged in hardness from about 30 to 260 ppm. The hardness of nearly all the surface supplies was below 60 ppm., while the hardness of most of the ground supplies was between 60 and 200 ppm.

Hardness of Public Supplies

Table 1 gives the population served and the hardness of the 66 public water supplies considered in this investigation. Where a city also sup-

FIG. 1. Hardness of Public Water Supplies in Georgia

plies other communities, the total population served is given. The hardness results were determined from the analytical data available. If a

system was supplied by more than one source, the average hardness was calculated from the percentage of supply from each source and the hardness of each. There will be some variation from the hardness figures given, but, in general, the results are representative. For most of the places using well waters, changes in the percentage of supply obtained from different wells will not alter greatly the hardness of the water furnished consumers. There were, however, several exceptions, e.g., at East Point the extremes in hardness of the raw waters from three wells were 49 and 260 ppm.; at Sandersville 90 per cent of the supply was obtained from a well having a hardness of 34 ppm. and 10 per cent from 2 wells having a hardness of about 180 ppm.

Averages of the hardness results for the finished water as given in Table 1 are 29 ppm. for the surface supplies, 123 ppm. for the ground supplies, and 77 ppm. for all supplies. It should be understood that the average figure for all supplies may be appreciably affected by the proportional number of ground and surface systems. The weighted average hardness of the finished water, in which the hardness of the water at each place is weighted in proportion to the population served, is 25 ppm. for the surface supplies, 115 ppm. for the ground supplies, and 53 ppm. for all supplies. The cities for which data are given in Table 1 are shown on Fig. 1 with symbols corresponding to four groups of hardness for the water delivered to consumers.

The first group includes cities having hardness in the range of 1 to 60 ppm. Water of this degree of hardness is considered soft. The second group includes cities having hardness in the range of 61 to 120 ppm. The waters of this group may be considered to have a moderate degree of hardness. The third group includes cities having hardness of 121 to 200 ppm. Waters in the upper range of this group may be considered hard. Municipal softening particularly for those supplies in the upper part of the range will be beneficial as well as economically profitable. The fourth group, hardness 201 ppm. and above, includes only two of the 66 public supplies, namely, Brunswick (hardness, 205 ppm.) and Cairo (hardness, 621 ppm.). Waters of this group may be considered hard to very hard. Softening should be considered for the public supplies which fall in this range of hardness. Occasionally water may be so hard that the cost of softening is more than the community will bear regardless of the advantages and savings effected from the use of soft water.

Table 2 gives the number of consumers using water of different degrees of hardness from the 66 supplies investigated. The table shows that by far the larger number of people are furnished water with hardness in the first group, i.e., hardness of 1 to 60 ppm. All the finished surface waters fall

within this group except those for Rockmart (hardness, 63 ppm.) and Rossville (hardness, 72 ppm.). At times the raw water hardness at Dalton considerably exceeds this limit, but during those times it is generally

TABLE 2

Number of Persons Using Water of Different Degrees of Hardness

RANGE OF HARDNESS IN PPM.	POPULATION		
	Surface	Ground	Total
1–10	0	0	0
11–20	119,907	4,953	124,860
21–30	500,580	0	500,580
31–40	77,461	0	77,461
41–50	44,086	12,608	56,694
51–60	10,448	34,521	44,969
1–60	752,482	52,082	804,564
61–80	7,302	0	7,302
81–100	0	57,657	57,657
101–120	0	141,988	141,988
61–120	7,302	199,645	206,947
121–140	0	30,064	30,064
141–160	0	29,802	29,802
161–180	0	2,579	2,579
181–200	0	5,175	5,175
121–200	0	67,620	67,620
201–250	0	15,035	15,035
251–300	0	0	0
301–350	0	0	0
351–400	0	0	0
401–450	0	0	0
451–500	0	0	0
501–550	0	0	0
551–600	0	0	0
601–650	0	4,653	4,653
201–650	0	19,688	19,688
Totals	759,784	339,035	1,098,819

softened to about 60 ppm. Likewise is it shown that more than half the people using ground water from the larger public supplies are served with water of hardness between 61 and 120 ppm.

Some Physical Effects of Bombing

By Herman G. Baity

SINCE most wartime hazards to public water supply and sewerage systems probably come from high explosives, it is quite appropriate that some of the well-established facts regarding bombs and similar implements of destruction and their effects upon public utility targets be reviewed. This paper presents no new knowledge, but is a restatement of certain data long ago developed by ordnance experts, proved in the theaters of war during the last two world-wide cataclysms, and currently appearing in many popular and technical journals.

Anatomy of Bombs

Constituent Parts: Bombs which are designed to be discharged from airplanes consist of the following essential parts: (1) a thin steel shell of streamlined shape to reduce air resistance; (2) thin metal vanes on the tail of the projectile to guide its flight through the air; (3) a heavy pointed nose of hardened steel for penetration of target objectives or the piercing of armor; (4) a fuse that is ignited on impact, and which may be of the instantaneous or time-train delayed action type; (5) a detonator charge which is ignited by the fuse and which, in turn, explodes the main bursting charge (or rips open the shell container in the case of gas bombs); and (6) the main burster charge of T.N.T. or other relatively stable high explosive material. As compared with projectiles shot from cannon the shell walls of bombs are much thinner, since they do not have to resist the stress caused by the propulsion and rifling of a gun. Consequently, their charge of high explosive is proportionately much greater, often amounting to 40 to 60 per cent of the total weight of a demolition bomb and as much as 90 per cent of the weight of an aerial mine.

Types and Sizes of Bombs: Bombs may be classified into the following types as to their construction, size and purpose (see Fig. 1):

A paper presented in outline on January 28, 1942, at the Symposium on Protection of Public Water Supplies in Wartime, Chapel Hill, N.C., by Herman G. Baity, Prof. of San. Eng., School of Public Health, Univ. of North Carolina, Chapel Hill.

1. *Demolition bombs*, having a weight range from 100 to 4,000 lb. (usually 550 lb.), a relatively thin casing and heavy explosive charge, a fuse timed for either instantaneous or delayed burst, the purpose of which is primarily the destruction, by concussion, of civilian and military structures and utilities.

2. *Armor piercing bombs*, with a weight range of 200 to 4,000 lb. (usually 1,100 lb.), a heavy shell-wall and a sharp massive nose of specially hardened steel, a proportionately smaller charge of explosive, and a delayed action fuse, the use of which is against warships, forts and other armored targets.

3. *Fragmentation bombs*, having sizes ranging from 17 to 2,000 lb. (usually about 30 lb.), a heavy serrated shell of steel or cast iron designed to sepa-

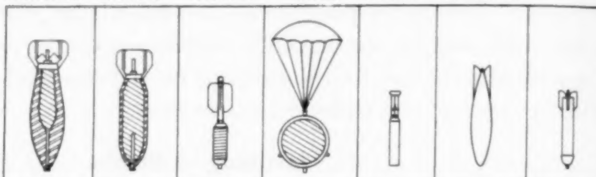
	ARMOR PIERCING	DEMO-LITION	FRAGMEN-TATION	AERIAL MINE	INCENDIARY LIGHT	INCENDIARY SCATTER	GAS
TYPE OF BOMB							
USUAL WEIGHT-LB.	1100	550	30	2000	2	30	30
RANGE OF WEIGHT	200-4000	100-4000	17-2000	1000-5000	2-60	17-500	30-600
SECTIONAL PRESSURE	9.7	3.1	2.0	-	0.3	1.5	1.5
PERCENT OF EXPLOSIVE	10-15	40-60	15	90	-	-	-
TERMINAL VELOCITY-FPS.	1400	1100	725	-	350	-	-
PENETRATION	EXCELLENT	GOOD	POOR	POOR	POOR	FAIR	POOR
BLAST	REDUCED	HEAVY	LIGHT	EXT. HEAVY	NONE	NONE	NONE
USED AGAINST	WARSHIPS AND SPECIAL TARGETS	BUILDINGS BRIDGES AND MILITARY CONCEN-TRATIONS	PERSONNEL AND TRANSPORT	WHOLESALE DEMOLITION OF WEAK STRUCTURES OVER WIDE AREA	TO CAUSE FIRES FOR DIRECT DAMAGE AND TO ILLUMINATE THE TARGET		PERSONNEL CONTAM-INATION

FIG. 1. Types and Characteristics of Bombs (From *The Military Engineer*)

rate into many uniform fragments, a proportionately smaller charge of explosive than is used in demolition bombs, and an instantaneous type of fuse, which is intended primarily for the destruction of human life and transport facilities.

4. *Aerial mines*, with weights ranging from 1,000 to 5,000 lb. (usually 1,000 lb.), a thin spherical steel casing equipped with multiple contact fuses, a very high weight proportion of explosive, ordinarily launched with an attached parachute with the objective of demolishing weak structures or destroying personnel over an extended area by the force of its tremendous explosive power.

5. *Light incendiary bombs*, having weights varying from 2 to 60 lb.

(usually 2 lb.), a thin magnesium shell filled with thermite or other high temperature agent not easily extinguished, either an instantaneous or delayed-action fuse, and an igniter charge, which is intended to burn where it falls without explosive action and quietly start fires for the destruction of property or the illumination of other targets.

6. *Scatter incendiary bombs*, having a weight range of 17 to 500 lb. (usually about 30 lb.), a thin, easily ruptured shell filled with thermite or similar material, usually a delayed-action fuse, and a small igniter and exploder charge which is designed to scatter the burning agent over a considerable area and provide multiple sources for the conflagration of materials within enclosed spaces.

7. *Gas bombs*, having a weight range of 30 to 600 lb. (usually 30 lb.), a thin shell, housing a lead gas-containing envelope, a relatively heavy charge of liquid or highly compressed gas, a contact fuse, and a small exploder charge for bursting the bomb casing, which is used to kill, disable or terrify civilian or military personnel.

Types of Bursts: Depending upon fuse types and settings, bomb bursts may be classified into the two following types:

1. *Instantaneous*, usually employed in connection with aerial mines, fragmentation, gas, and some incendiaries, where the motive is to have the explosion or disruption of the casing occur almost simultaneously with the contact of the bomb's nose with the target.

2. *Delayed*, usually used with demolition, armor-piercing and most incendiary types, where there is an advantage in having the bomb penetrate the target before detonation occurs. It is with the tremendously destructive ability of this type that municipal officials are primarily concerned in connection with the protection of water and sewer services.

Types of Shell Filling Materials: As to the types of filling materials used in the various kinds of bombs, the following classification may be made:

1. *High explosive*, where the material is the relatively stable trinitrotoluene, popularly known as T.N.T., or one of the newer, less stable, but more powerfully explosive filling agents.

2. *Incendiary*, in which the filler is thermite powder, a mixture of aluminum and iron oxide which burns at high temperatures, and which ignites the magnesium case producing a temperature of about 5,000°F.

3. *Gas*, in which the filling material is one of the various toxic or irritant gaseous compounds compressed usually to a liquid state. Several hundred gases have been investigated for such use, of which about 60 have been considered adaptable. Of these, the most important are:

Lewisite, chlorvinyl dichlorarsine	($CHClCh—AsCl_2$)
Mustard, di-chlorethyl-sulfide	$S(CH_2CH_2)_2Cl_2$
Phosgene, carbonyl chloride	($COCl_2$)
Diphosgene, trichlormethyl chloroformate	($ClCOOC—Cl_3$)
Adamsite, diphenylaminechlorarsine	($(C_2H_4)_2—NHAsCl$)
Ethyldichlorarsine	($C_2H_5—AsCl_2$)
Chlorpicrin, nitrochloroform	(CCl_3NO_2)

Trajectory of Bombs

Path and Angle of Impact: When a bomb is released from an airplane in flight it is acted upon during its descent by two forces, the pull of gravity and the resistance of the air. Due to its initial horizontal velocity, the

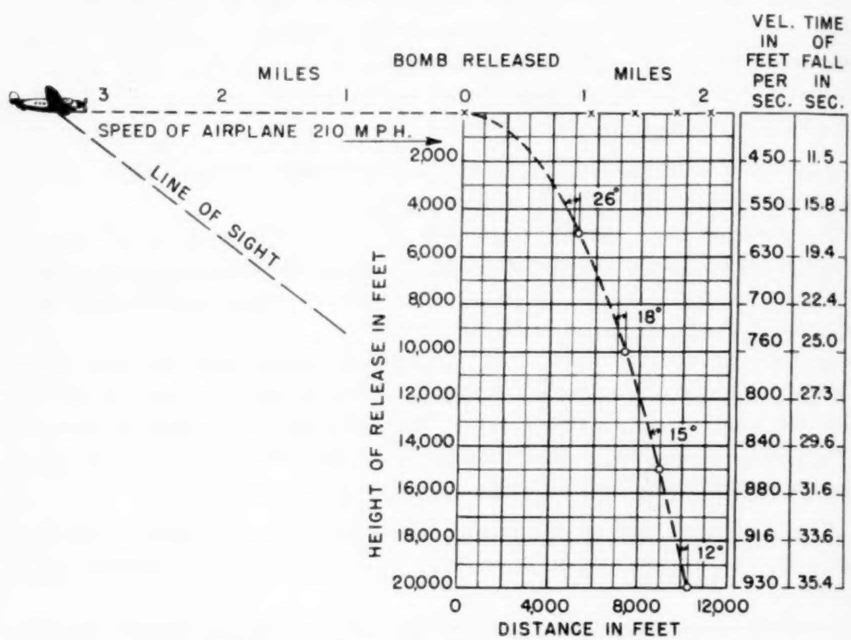


FIG. 2. Trajectory of Bomb Released From Plane Flying at 210 mph. at 20,000 ft. Altitude (From *The Military Engineer*)

same as that of the plane, it travels with this component of velocity diminished only by air friction. Consequently, the carrier plane would be approximately over the target at the time of impact, if it continued in a straight line of flight with uniform speed. Stated another way, the bombardier at high levels aims on his target and releases the bomb long before the plane reaches a position vertically over it. From Fig. 2 it may be observed that in a plane flying at a speed of 210 mph. and at a height of

20,000 ft. the bombardier would release his bomb 10,400 ft., or about 2 mi. in back of the target. Due to the acceleration of gravity, the path described by the bomb is approximately parabolic. The exact shape of this trajectory depends upon such factors as the height and speed of the bomber, wind velocity and direction, barometric pressure, etc.

The ordinary citizen has the impression that air bombs fall vertically. The simple ballistic facts indicated above show that this is quite erroneous. Table 1 indicates the angles of impact with the horizontal at which bombs would strike their target when dropped from planes flying at various speeds and elevations. For example, a bomb from a plane flying at 200 mph. and at a height of 2,000 ft. would strike at an angle of only 53 deg. with the ground.

TABLE 1

*Angle of Impact With Horizontal for Various Plane Speeds and Altitudes**

ALTITUDE	ANGLE OF IMPACT WITH HORIZONTAL FOR VARIOUS SPEEDS			
	140 mph.	160 mph.	180 mph.	200 mph.
ft.	*deg.*	*deg.*	*deg.*	*deg.*
2,000	61	58	55	53
4,000	69	67	65	62
6,000	73	71	69	67
8,000	76	74	72	70
10,000	77	75	74	72
12,000	79	77	77	74
15,000	80	79	79	76
20,000	82	81	81	78

* From *Engineering News-Record.*

The average man in the street likewise has the mistaken notion that bombs strike only the roofs of buildings. Due to the angles of impact of the projectiles they are often equally or more than likely to strike the sides of buildings, especially tall structures. Considering the example of a building which is 100 ft. x 200 ft. in plan and 400 ft. in height (Fig. 3), the horizontal projection of the roof is 20,000 sq.ft., but the target offered to a bombardier flying at 200 mph. at an elevation of 6,000 ft. is 49,670 sq.ft. In this case the chance of hitting the building at some point is two and one half times that of hitting the roof only.

In seeking shelter from bombs many people have the idea that safety is afforded at any position in a tall building below the floors likely to be affected by roof penetration and above those likely to suffer from shell splinters of bombs bursting in adjacent streets. They also imagine that bombs striking the sides of the building would ricochet off into the streets

below. They forget about the large areas of vulnerable window space, and fail to appreciate the fact that bombs striking masonry walls even at acute angles would probably be traveling at such high velocities as to penetrate them without deflection or material impedance. Protection would be greatest in the interior spaces of skyscraper structures, as far removed as possible from exterior walls.

Terminal and Impact Velocities: The velocity attained by a bomb at the time of impact depends upon the type of bomb and the height and speed of the bomber. In Table 2 are indicated the impact velocities of a 500 lb. demolition bomb dropped under various conditions of altitude and velocity.

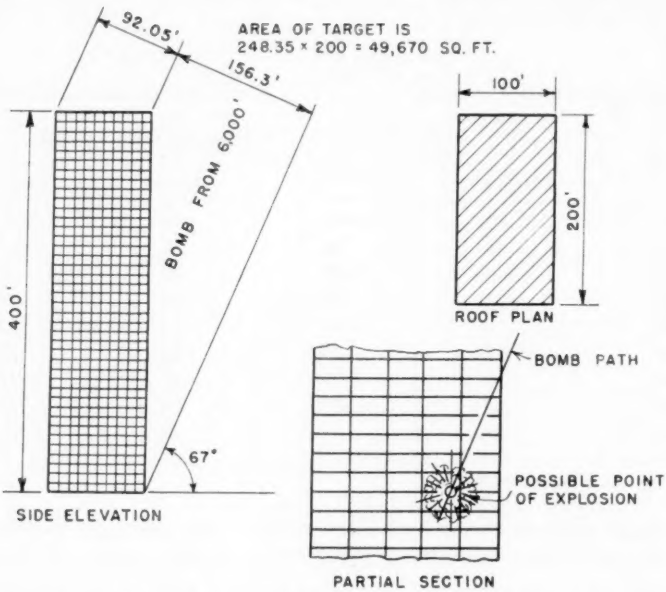


Fig. 3. Target Provided by Tall Building for Plane Flying at 200 mph. at 6,000 ft. Altitude

The maximum attainable terminal velocity of bombs is limited by the air resistance encountered, the shape, type, specific gravity and streamlining of the projectile. These maximum velocities are shown in Fig. 1, and for a demolition or armor-piercing type may amount to 750 and 955 mph. respectively.

Channels of Destruction of High Explosive Bombs

Bursting bombs inflict their destructive action on life and property through energy of impact, fragmentation of the casing, shock of explosion and the vacuum effect following immediately the air blast.

Kinetic Energy of Impact: This effect, due to the physical collision of the bomb with its target, depends for its magnitude upon the weight of the bomb and its striking velocity. The energy released through this channel by a 100-lb. bomb dropped from a 20,000-ft. height amounts to about 1,500,000 ft-lb. From the same height, 550-lb. and 2,200-lb. bombs release on impact about 8,500,000 and 33,500,000 ft-lb. of energy, respectively.

Fragmentation: Upon explosion, a bomb casing disintegrates into many fragments which are thrown with terrific velocity in all directions. In the case of a demolition bomb these are steel splinters of irregular shape and size; with serrated fragmentation bombs they are slugs or pellets of more uniform size. For a 100-lb. projectile the number of fragments is about 4,500, and they are propelled by the explosion at initial velocities of about

TABLE 2

*Impact Velocities of a 500-Pound Demolition Bomb**

ALTITUDE	IMPACT VELOCITY FOR VARIOUS SPEEDS			
	140 mph.	160 mph.	180 mph.	200 mph.
ft.	*fps.*	*fps.*	*fps.*	*fps.*
2,000	400	410	430	440
4,000	520	530	540	550
6,000	610	620	620	630
8,000	680	680	690	700
10,000	740	740	750	750
12,000	790	790	800	800
15,000	850	850	860	860
20,000	930	930	930	930

* From *Engineering News-Record.*

5,000 fps.—approximately twice the muzzle velocity of a high-powered rifle.

While their carrying power is not so great as rifle bullets, due to their non-streamlined shape, the radius of lethal effect of these flying fragments varies from about 200 ft. for a 100-lb. bomb to 1,200 ft. or more for the heaviest types. The cone of dispersion of the splinters depends largely upon the fuse setting, which governs the penetration before the burst. For contact or above-ground bursts the dispersion of fragments is 180° or more, while delayed bursts in the earth usually result in a dispersion of 90° or less, due to the protection afforded by crater walls. For protection against fragments, personnel should seek ditches, doorways, walls or parapets, or fall prone on the ground. Due to the shielding effect of the crater, a person lying on the ground is usually safe at a distance of 30 ft. from the

point of burst of a 100-lb. bomb equipped with a delayed fuse. The following table from *Engineering News-Record* shows the minimum thicknesses of materials which have been found by the British to afford protection against splinters at a distance of 50 ft. away from a 500-lb. demolition bomb burst:

Mild steel plate	1½ in.
Solid brickwork or masonry	13½ in.
Reinforced concrete	12 in.
Plain concrete	15 in.
Earth and sand	30 in.
Ballast or broken stone	24 in.
Wood, minimum	40 in.

Shock of Explosion: In bursting, a steel bomb shell is expanded to perhaps twice its normal size before rupturing with terrific explosive energy. This pressure phase of the explosion lasts for about 0.005 sec. and the kinetic energy released by a demolition bomb amounts to 40 or 50 times that caused by physical impact. The explosive energy of a 550-lb. bomb probably exceeds 400,000,000 ft-lb. In contact with air this explosion compresses it tremendously and sets in motion a destructive wave action known as "blast." In contact with earth the bomb explosion generates a compression wave known as "earth shock." It is obvious that the maximum damage to structures and underground services can be effected by high explosive bombs which are equipped with delay-action fuses to permit considerable penetration of the target before the burst occurs.

The penetration of a bomb before bursting depends on its type and weight, the nature of material penetrated and the fuse setting. A 500-lb. demolition bomb dropped from a plane 25,000 ft. high and striking with an impact velocity of about 1,000 fps. will penetrate 4 ft. of concrete, possibly the roof slab and five 6-in. reinforced concrete floors, from 10 to 12 floors of 4-in. cinder concrete, or from 15 to 25 ft. in clay soil.

The sizes of the craters produced in the earth depend upon the size of bomb, its penetration, and the nature of the soil. In paved streets, and with delayed fuses, average values are:

	Size of Crater	
Weight of Bomb	*Depth*	*Diameter*
100 lb.	6 ft.	12 ft.
500 lb.	10 ft.	20 ft.
2,000 lb.	14 ft.	40 ft.

Much larger craters are produced in penetrable clay or sandy soils. A 2,200-lb. bomb may penetrate 40 ft. in sandy loam and move more than 1,000 cu.yd. of earth. A 100-lb. bomb may penetrate 6 to 8 ft. and open a crater of more than 25 cu.yd. in volume.

The radiuses of destructive air blasts and earth shocks also depend upon the size of bomb, its penetration and the nature of the target. In paved streets, bombs equipped with delay-fuses exercise a destructive action by blast and shock at distances indicated below:

	Radiuses of Destruction	
Weight of Bomb	*Earth Shock*	*Air Blast*
100 lb.	22 ft.	70 ft.
500 lb.	45 ft.	200 ft.
2,000 lb.	70 ft.	400 ft.

British experience has shown that water and sewer mains are broken at lateral distances of 60 to 120 ft. from bomb craters, and partial destruction may occur at even greater distances. Such lines with 40 to 50 ft. of cover are not immune to destructive earth shocks. It has been found that air raid shelters must be constructed 60 to 80 ft. underground and provided with stout roof structures if they are to be considered safe against direct hits.

Vacuum Following Blast: The fourth channel of bomb destruction is the suction effect of the air rushing back into the partial vacuum created by the intense explosion. This follows immediately after the 0.005-sec. blast and lasts for approximately 0.030 sec. at a lower intensity. At a distance of 30 ft. from a 550-lb. bomb explosion its magnitude is about 4 to 5 psi. This effect, acting in a direction opposite to that of the preceding blast, is sufficient to pull great heaps of debris toward the point of burst.

Vulnerability of Various Types of Construction

From the nature of the destructive forces in bombing it is apparent that buildings which have bearing walls of masonry construction, where weight is depended upon to hold them in place, are exceedingly vulnerable. Skeleton frame structures of steel or reinforced concrete, where the weight is carried by heavy columns and girders are much more resistant. Windows and curtain walls may be blown out, and even a few columns or beams ruptured, but the building as a whole remains intact. It has been found that buildings having structural steel frameworks are generally more resistant to bomb damage than those with concrete frames due to the fact that explosions loosen the bond of the reinforcing and fragments tear away the concrete from the steel.

Probability of Bomb Hits on Vital Structures

Assuming that bombing is of the nocturnal, high level, random type rather than directed at specific targets, the chance of hits on particular structures will be in the general ratio of the area covered by such structures

to the total area of a city or community. Water and sewage works officials are especially concerned over the probability of hits upon their vital structures and service mains. Some solace should be found in the reports from Britain that, so far, not a single water purification works, power station, or sewage treatment plant has been put out of commission or seriously damaged in more than two years of almost incessant bomb attack.

It is estimated that in New York City, our most compactly built metropolitan center, the area distribution is: buildings, 40 per cent; streets, 30 per cent; parks and other open spaces, 30 per cent. In the average American city the building coverage is estimated at not more than 20 per cent of the total area, with street areas of 10 to 20 per cent and with open spaces accounting for the remaining 60 to 70 per cent. The smaller sprawling cities and towns offer an even smaller area ratio of vital structures and utilities as the targets for enemy bombardiers.

Modification of the Fluoride Determination—Addendum

By R. D. Scott

The author wishes to bring to the attention of the field a change and an additional notation concerning the fluoride procedure as published in his paper "Modification of the Fluoride Determination" (Jour. A.W.W.A., **33**: 2018 (1941)).

Further study has shown the acid content of the reagent to be more critical than was previously realized. While it is desirable to have a rather large quantity of acid present in order to suppress interference of sulfate and chloride when these ions are present in unusually high concentration, too much acid lessens the color contrast of the higher concentrations of F^-.

Conversely, the color contrast with small F^- concentrations is thereby sharpened and, in fact, the strength, as presented in the published procedure, 3 N is well suited for distinguishing between such concentrations as 0 and 0.05 or 0.05 from 0.1 ppm. F^-. However, in order that 1.4 ppm. may be distinguished from 1.5 ppm. F^-, the normality of the mixed acids should not exceed 2.7. Accordingly the procedure under 1.3 should be changed to read:

"Prepare an approximately 2.7 N hydrochloric acid solution by diluting 112 ml. of concentrated acid, sp.gr. 1.19, to 500 ml. and an approximately 2.7 N sulfuric acid solution by diluting 37 ml. of concentrated acid, sp.gr. 1.84, to 500 ml. After cooling, mix the two acid solutions. The final strength may be checked by titration. . . ."

Discussions of

Trends in Coefficients of Large Pressure Pipes—Charles H. Capen

By Weston Gavett, John Hedberg, Charles H. Capen and Richard Hazen

EVERYONE who must deal directly with the problem of measuring or estimating the flow of water in pipes is confronted sooner or later with the necessity of using either a formula or set of tables to estimate such flows. Unlike the structural engineer, the hydraulic engineer has, by custom, developed the habit of calculating his flows and pipe sizes down to a fine point of determination that allows little, if any, leeway. Largely because of this, the choice of any empirical formula for determining such flows is of paramount importance. More than a few eminent hydraulicians have lived to see their estimates go awry and some have been brought strictly to account.

The original article on "Trends in Coefficients of Large Pressure Pipes" was written primarily not only to warn engineers of the pitfalls that exist, citing some of the instances of malperformance, but to serve as a guide to those who have such problems in the future. Mr. Capen has summed up the situation briefly, as follows:

1. Many large pipe lines have not performed as expected.

2. The cost involved in such projects is so large that someone—usually the engineer in charge of design—is frequently held responsible.

3. Tests on large pipe lines are not undertakings that can be accomplished easily. Careful preparation and training of personnel are necessary if dependable results are to be obtained. For this reason, the number of reliable records is rather limited and conclusions can be drawn from them only by a most careful consideration of the conditions surrounding the individual tests.

4. An exhaustive study of the literature, supplemented by some individual tests and by selection of typical results culled from the available

A series of discussions emanating from material originally published in the January 1941 issue of the JOURNAL.

data, has led Mr. Capen to select the modified Mills formula as the most dependable for general use.

5. The Williams-Hazen formula was based on a large series of tests available at that time and represented a good approximation of the normal results to be expected. The fact that Mills arrived at a somewhat different answer is primarily because he confined his study to tests made under the most exacting conditions by well qualified experimenters rather than by taking an average of all the results available in the entire field of water conduits.

6. The excellent tables published for the Williams-Hazen formula, together with the distribution of slide rules for rapid calculation of the formula, led to its wide acceptance. Its exponents, however, make it cumbersome to use by direction solution of the formula. No one can deny that the tables have been of tremendous benefit to water works men, but if, as Mr. Capen believes, the time has come to supplement them by a formula more nearly in accord with facts, customs should be changed, particularly for large pipe design.

The very fact that construction of test sections of large pipes is prohibitive in cost leads to consideration of the use of models. This immediately brings to the foreground the use of Reynolds number, as discussed in the succeeding contributions.

Discussion by *Weston Gavett*.* Mr. Capen, by presenting the results of his careful studies on the frictional losses in large pipes has again rendered the water works profession a real service. The variety of the pipes investigated, with respect to size, type, age and condition provides valuable data for evaluating various formulas on pipe flow. His conclusion that the frictional loss varies as the second power of the velocity rather than some smaller fractional power, for the range of diameters and velocities studied, appears well substantiated. With the formula he suggests, hydraulic computations will be simpler and more accurate.

While the paper is obviously intended for the practical water works man, the fluid mechanicians should not be distressed over the simplicity of the formula advocated. For the range studied, the use of 2 for a coefficient of V in the expression for loss of head seems entirely proper, with all due deference to the Reynolds number. This number, so frequently mentioned in present day papers on hydraulics, is not as familiar as other factors such as D, V, S, etc., possibly because it is usually encountered in formula form rather than numerically in tables or on charts. That, at least, is the writer's reaction to **R**, or R_e, and he has been inclined to agree with some authorities that the Reynolds number is of slight importance

* San. & Hydr. Engr., Plainfield, N.J.

for pipe studies in the range of sizes, velocities and viscosities encountered in general water practice. In an attempt to visualize **R** in terms of diameters and velocities, a simple diagram (Fig. 1) has been plotted to show the relationship between **R**, D and V. A temperature of 15°C. was used. To prepare this diagram the following data* were used:

$$\text{Reynolds number} = \mathbf{R} = \frac{VD}{\nu}$$

Where V = velocity, in feet per second
D = diameter of pipe, in feet
ν = kinematic viscosity

The kinematic viscosity is equal to $\frac{\mu}{\rho}$, or the absolute viscosity μ divided by the mass of the liquid, ρ

The mass ρ is equal to the weight per unit volume divided by gravitational acceleration.

At 15°C., ν, the kinematic viscosity was found (from a table) to be 0.0000123. This value may be derived as follows:

From Poiseuilles formula

$$\mu = \frac{0.00003716}{1 + 0.03368T + 0.000221T^2} = 0.0000239 \text{ for } 15\,^\circ\text{C}.$$

For foot, pound and degree Centigrade units

$$\rho = \text{mass} = \frac{62.38}{32.16} = 1.9397$$

$$\nu = \frac{\mu}{\rho} = \frac{0.0000239}{1.9397} = 0.0000123+$$

Mr. Capen's designation of his coefficient as F_m in honor of Hiram Mills seems entirely proper and a long delayed recognition of the remarkable work done by Mills. His book, "Flow of Water in Pipes" (3), published in 1923 after his death, contains his voluminous studies as compiled from his notes by John R. Freeman and Karl R. Kennison. In the introduction, Mr. Freeman notes that Mills' first experiments were made in 1872 and that his fundamental formula $R^{\frac{2}{3}}I = CV + C_1V^2$ was developed shortly after that time. It is important to note that publication of Reynolds' work is generally placed in about 1880. Much of Mills' work was done prior to that time.

---

* Formulas for μ and ν are those given by Gibson (1). King's handbook (2) gives formulas and tables for lower and higher critical velocities based on Reynolds numbers.

Swindin in "Modern Theory and Practice of Pumping" (4) comments sarcastically on the use of exponential formulas rather than an expression for resistance to flow in two terms, one with the first power and the other with the square of V, a relationship shown by Stokes, Dr. Young, and Lord Kelvin. The diagrams and tables prepared by Mills, showing the coefficients C and C_1, indicate a remarkable agreement with observed data, and show distinctly the lower and higher critical velocities, with friction dependent on V in the lower range, a transition zone where both coefficients increase and an upper zone where both C and C_1 are constant in value. It should be noted that Mills used Saph and Schoder's experi-

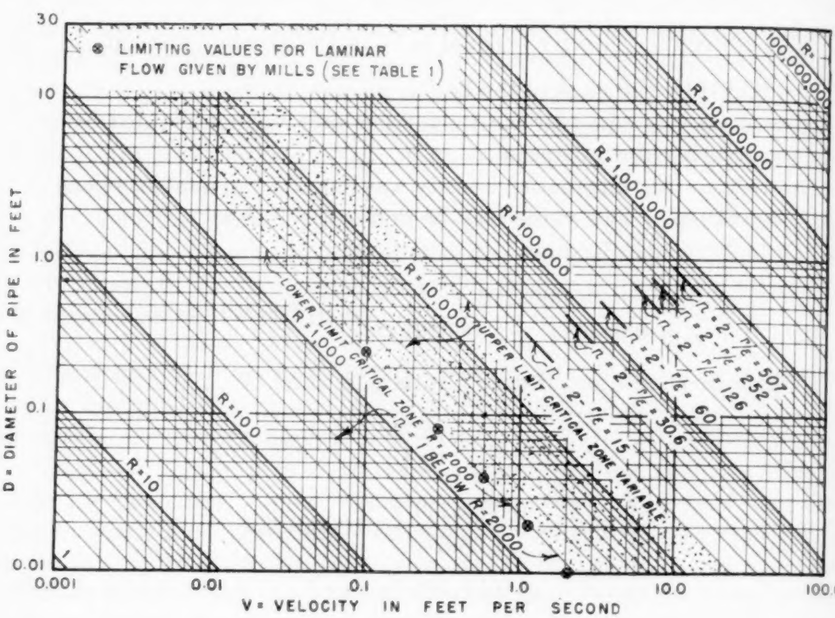


FIG. 1. Reynolds Number, **R**, for Water at 15°C.

ments on small pipe to illustrate conditions in the lower ranges, and that these authors pointed out the laminar flow conditions below the critical velocity.

Another interesting feature in Mills' book is his plotting of the velocity distribution in a 12-inch pipe, obtained by the use of a specially designed pitot tube, where he shows a parabola for the central 80 per cent of the diameter with a transition in the curve adjacent to the walls. This he designated as the "probable zone of disturbed motion or eddying, originating in the perimeter and limited by point where curve of velocities breaks away from a true parabola." Present-day theory locates the laminar zone adjacent to the pipe wall with turbulent flow in the central zone.

Mills noted and gave formulas for the variation of the lower critical velocity below which the resistance varies with the first power of the velocity. A comparison of the values of Table 1 (3, p. 84) for the lower critical velocities and the curve (Fig. 1) will show a close agreement with **R** = 2,000.

The writer has included the foregoing notes from Mills' book because they seemed of general interest and emphasize the propriety of honoring Mills by the designation of a useful coefficient with his name. It is obvious that Mills was well in advance of his contemporaries in his work on hydraulics.

Hunter Rouse (5) has given a résumé of present day fluid mechanics relating to pipe flow. His paper includes a chart showing the variation of f with **R**. This curve indicates that the hydraulic radius at which the exponent of V is 2 is dependent on **R** and the roughness of the pipe. The chart indicates that the observations reported by Capen with Reynolds

TABLE 1

*Relation of Diameter to Critical Velocity as Determined by Mills**

DIAMETER		VELOCITY	REYNOLDS NUMBER
in.	*ft.*	*fps.*	
$\frac{1}{8}$	.01	2.07	1683
$\frac{1}{4}$	.02	1.1	1789
$\frac{1}{2}$	.04	0.6	1951
1	.08	0.3	1951
3	.25	0.1	2033

* See Fig. 1 for plotting of points.

numbers of 580,000 to 2,080,000 fall in the portion of the curve where f is constant, or the coefficient of V is 2.00. For smaller pipes and lower velocities the use of V^2 might be subject to some question, although, as Capen points out, the error in using 2 as an exponent may be small compared with possible errors in assumption of coefficients. For smooth pipe, the formula $H = \dfrac{CV^{1.75}}{D^{1.25}}$ as given by Saph and Schoder for brass pipe appears well substantiated. For pipes with roughness between those giving exponents of V of 1.75 and 2.00, no single exponential formula can be precise. The exponent corresponding to the degree of roughness should be used, or the exact Mills formula with proper coefficients for V and V^2.

On Fig. 2 are plotted an exponential formula for smooth pipe, $H_f = 0.3V^{1.75}$, from Schoder and a formula of the Mills complete form with coefficients to provide coincidence with the exponential formula at $V = 1$ and $V = 10$, $H_f = 0.146\ V + 0.154\ V^2$. In both forms, D is taken as 1,

to simplify. It will be noted that between the two values of V, the two formulas are reasonably close together. Below 1 fps. and above 10 fps., the two curves diverge and there seems little doubt that the Mills type of formula will be correct over a much greater range of velocities. For higher velocities, the Mills type curve approaches a straight line with slope or exponent of V of 2.00.

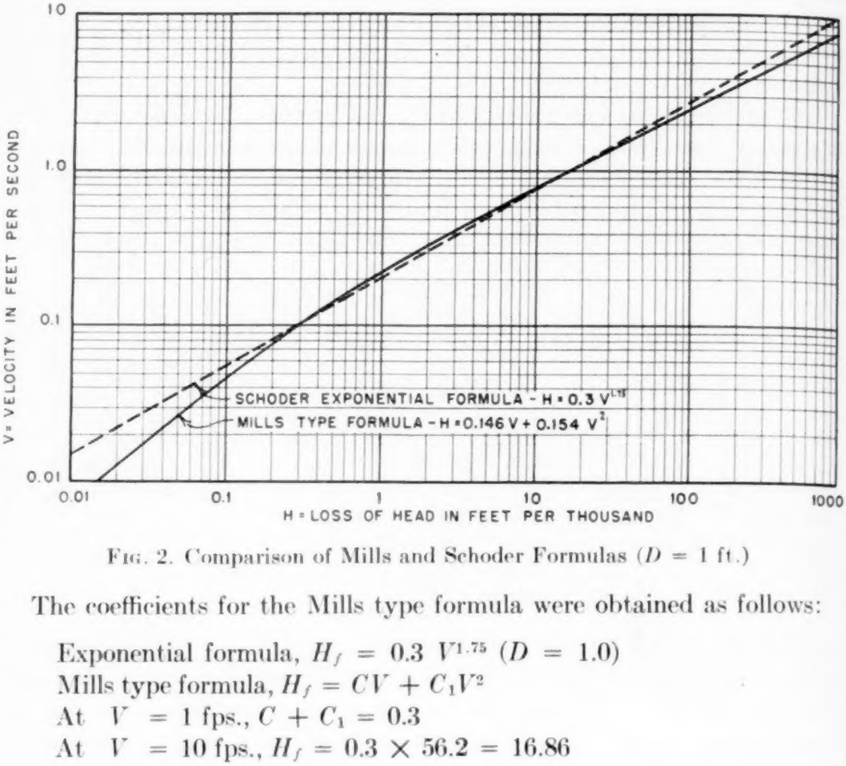


FIG. 2. Comparison of Mills and Schoder Formulas (D = 1 ft.)

The coefficients for the Mills type formula were obtained as follows:

Exponential formula, $H_f = 0.3\ V^{1.75}\ (D = 1.0)$

Mills type formula, $H_f = CV + C_1V^2$

At $V = 1$ fps., $C + C_1 = 0.3$

At $V = 10$ fps., $H_f = 0.3 \times 56.2 = 16.86$

$$C = (0.3 - C_1)$$

$$10\ (0.3 - C_1) + 100\ C_1 = 16.86$$

$$C_1 = 0.154$$

$$C = (0.3 - 0.154) = 0.146$$

$$D^{\frac{5}{4}}H_f = 0.146\ V + 0.154\ V^2$$

The exponent of d of 1.25 also has impressive support and appears to hold for rough pipe as well as smooth. The exponent of V seems to lie between 1.75 and 2.00 depending on the smoothness of pipe and the Reynolds number.

The value ϵ described by Rouse is a useful measure of the degree of roughness. It is used to represent the radial dimension of the roughness

particles. Curves in Rouse's paper show the effect of ϵ, based on experiments by Nikuradse on pipes artificially roughened by sand grains of various sizes. Rouse gives the relation between f and ϵ by the formula $\frac{1}{\sqrt{f}} - 2 \log_{10} \frac{r_0}{\epsilon} = 1.74$ where f is the coefficient in the formula

TABLE 2

Values for f *and* ϵ *(After Nikuradse) as Obtained From Field Tests of Large Pipe*

TEST NOS.	PIPE DIAMETER	PIPE AGE	REMARKS	f	ϵ
	in.	*yr.*			*in.*
P1, P2	48	31.5	Pequannock Conduit No. 1—riveted pipe, 7 = ft. lengths	.0426	0.66
P3	48	31.5		.0409	0.60
P4	48	41		.0445	0.76
P5, P6, P7, P8	48	45.1		.0401	0.56
P9	48	48		.0421	0.65
P10, P11, P12	48	27.4	Pequannock Conduit No. 2 (48-In. Portion)—riveted pipe, 7-ft. lengths, before lining	.0348	0.37
P13, P20	48	39.2		.0473	0.894
P14, P15, P16	48	39.2–40	Same, after lining	.0184	0.037
P17	48	40.8		.0175	0.029
P18, P19	48	43.8		.0188	0.040
P27, P28, P33, P34	42	43.8	Pequannock Conduit No. 2 (42-In. Portion)—riveted pipe, 7-ft. lengths	.0489	0.85
P29	42	27.4		.0313	0.23
P30, P31, P32	42	27.4		.0375	0.40
R2	72	17	Rockaway Conduit No. 1—riveted steel, 7½-ft. lengths	.0346	0.55
R3	72	23		.0391	0.77
R7	72	4	Rockaway Conduit No. 2—lock bar, 30-ft. lengths	.0248	0.18
W 1, 2, 3, 4, 5, 6	74	0.6–0.8	Wanaque Pipes—lock bar, 30-ft. lengths	.0187	0.056
W 7, 8, 9, 10	74	1.2–1.3		.0158	0.028
W 11, 12	74	9.6		.0173	0.042
PV 3, 4	51	6.7	Passaic Valley Pipes—concrete lock joint, 12-ft. lengths	.0130	0.008

$\Delta h = \frac{fL}{D}\frac{V^2}{2g}$. From this formula, the writer has attempted to determine the values of ϵ in the tests reported by Capen. The values do not indicate the exact dimension of the tubercules, but perhaps represent the dimension of roughness particles, which if uniformly spaced, as in Nikuradse's experi-

ments, would give a loss equivalent to that caused by the roughness, rivets, joints and vertical and horizontal curves in pipes reported by Capen. Table 2 shows the values of f and ϵ for various tests described in Capen's paper.

On Fig. 1 is indicated the lower limit of the critical zone, or $\mathbf{R} = 2{,}000$, as well as the approximate value of $\mathbf{R}$ above which n, the exponent of V, is 2. These values are from Nikuradse's experiments on artificially roughened pipes as given by Rouse (6). The degree of roughness is designated by $\frac{r}{\epsilon}$ or the ratio of the radius of the pipe to the radius of the roughness particles.

In conclusion, the writer would like to express his admiration of Mr. Capen's courage in advocating the use of a simple formula of the V^2 type in the face of the general acceptance of exponential formulas by engineers over many years. While neither type is exact in the lower range of Reynolds numbers, it appears that the simple Mills formula will show a higher percentage of accuracy than the exponential type over the whole range of sizes and velocities encountered in water works practice. The use of the V^2 formula will greatly simplify the work of water engineers in many calculations.

Discussion by *John Hedberg*.* The writer finds himself in hearty agreement with Messrs. Capen and Gavett in the essential points of the former's paper and the latter's discussion of it. There can be no question of the validity and applicability of empirical formulas based on well conducted experiments. The danger lies in their use beyond the range of the actual experimentation.

The usefulness of the Reynolds number in the analysis of pipes is largely its service in enabling us to generalize a wealth of experimental data on many pipe sizes, and different fluids. We still lack a suitable criterion for surface roughness and until this is found, there is no justification for discarding the well-founded formulas of Mills, Williams and Hazen, Scobey and others.

Discussion by the Author—*Charles H. Capen.*† With his usual directness, Mr. Gavett has summed up the situation most adequately by saying: "the paper is obviously intended for the practical water works man." Consideration of viscosity and the Reynolds number was deliberately omitted from the text, but the references at the end of the article were

* Prof., School of Eng., Stanford Univ., Calif.

† Chief Engr., North Jersey District Water Supply Com., Wanaque, N. J.

intended to give an opportunity for further study to any who might wish to do so. The paragraph on "temperature" alluded to the fine points of viscosity corrections.

Now that the subject has been reopened it seems reasonable to start from scratch with the assumption that many engineers do not know just what Reynolds number signifies. An excellent, brief digest is given in *The Delaware Water Supply News* for April 15, 1939 (6), in which not only Reynolds number, but the lesser known Froude, Weber and Cauchy numbers are also defined. The following is quoted from that publication:

"In 1885, Professor Osborne Reynolds of the University of Manchester, England, further developed the principle of similitude. The great contribution of Reynolds to hydraulic theory was his recognition of the part that viscosity plays in so many hydraulic problems. Fluid friction is due to viscosity and in all problems having to do with flow in pipes and channels, a necessary condition for similarity between model and prototype is that the Reynolds number, **R**, shall be the same for both.

. . . .

"Since the region where the Reynolds number varies from 1,000 to 5,000 is one of hydraulic instability, in which the flow changes from laminar to turbulent, it is essential that the model and the prototype both stay on the same side of this region. In commercial practice, the change from laminar to turbulent flow is generally assumed at **R** = 2,000 to 2,200."

Application of Reynolds Number

The foregoing definition and explanation serve as a suitable technical basis but they do not reveal clearly to the average water works man what benefit may be derived from the every day application of these principles. In more simple language, what Reynolds attempted to do was to establish a relation by which experiments on small pipes (mainly as models) may be correlated to actual flow conditions in larger pipes or to flows with liquids of different viscosity. Thus in practical operation, if an engineer or water superintendent desires to predict what a large pipe, or series of pipes, will do under certain conditions, he has but to construct a small scale model, conduct experiments, and apply the observed records to the ratios indicated by Reynolds. The result will be the theoretical prediction of final operating conditions. This means that valves, penstocks, Venturi meters, pipe lines of all kinds, and, in fact, any water works appliance subjected to flow conditions, can be experimented upon in the form of a model and that the full scale results can be predicted from the experimental findings.

Professor Hedberg has furnished corroboration of the original findings of both Mr. Gavett and the writer, but slight exceptions are taken to two of his statements. One is to the effect that a suitable criterion for surface

roughness is still lacking. The excellent comparisons made by Mr. Gavett in adapting Nikuradse's experimental data to actual field observations (and incidentally the reasonableness of the results) suggest that the principles determined by Nikuradse may easily be made the basis for a criterion of roughness, empirical though it may be. For the present, therefore, this obstacle may be considered as overcome.

Considering this, together with all the facts now available regarding flow in large pressure pipes, the writer still believes, contrary to Professor Hedberg, that the value of the Mills formula has been sufficiently well established by Mills, Scobey, Gavett and the writer, and possibly by others, to warrant its adoption.

Fluid Flow Formulas

Probably to Poiseuille should go the credit for measuring viscosity of fluids, the subject on which most of this comment hinges. He developed the formula shown by Gavett. According to Reed and Guthe (7), Poiseuille also developed a formula for the flow of water in pipes, expressed by the equation:

$$Q = \frac{\pi p r^4 t}{8L\eta} \qquad (1)$$

where Q is quantity; p, the difference in pressure; r, the radius; L, the length; η, the coefficient of viscosity; and t, the time. By letting $Q = VA$ or $V\pi r^2$, dividing each side of the equation by πr^2, and transposing, we obtain:

$$p = \frac{8L\eta V}{tr^2} \qquad (2)$$

Substituting V for $\frac{L}{t}$, H for p, D for r and introducing the constant k to compensate for these changes where necessary,

$$H = k\eta \frac{V^2}{D^2} \qquad (3)$$

This may be seen to be similar in form to that derived by Scobey (8):

$$H = m\nu^{0.1} \frac{V^{1.9}}{D^{1.1}} \qquad (4)$$

the main difference being in the exponent of D.

For dynamic similarity of fluid in motion, Reynolds proposed the form:

$$\mathbf{R} = \frac{LV\rho}{\mu} \qquad (5)$$

where L is length; V, velocity; ρ, mass; and μ, absolute viscosity. Whether or not Reynolds intended that L should vary directly as the diameter is something that has not been well explained. At any rate, all current writers use the form:

$$\mathbf{R} = \frac{VD}{\nu} \qquad (6)$$

where D is substituted for L, and ν represents the kinematic viscosity or $\frac{\mu}{\rho}$. This is equivalent to saying that, for equal degrees of velocity and viscosity, the Reynolds number varies directly as the diameter. Conversely, if a pipe 10 ft. in diameter is to have the same Reynolds number as a pipe only 1 ft. in diameter, it must have one-tenth of the velocity.

In spite of suggestions by the hydromechanicians that the practical engineers give more heed to their teachings, Scobey is the only one of the modern writers who has presented a readily used and understood method of correcting for viscosity. Scobey started with the familiar Darcy formula:

$$h_f = \frac{fLV^2}{2Dg} \qquad (7)$$

Then using:

$$f = \frac{a}{\mathbf{R}^n} = a\left(\frac{\nu}{VD}\right)^n \qquad (8)$$

he derived the formula:

$$H = m\nu^y \frac{V^z}{D^x} \qquad (9)$$

where m is a constant representing the internal characteristics of the pipe. Scobey then returned to Reynolds' proposal that the sum of $z + x = 3$ to obtain

$$H = \frac{m\nu^{2-z} V^z}{D^{3-z}} \qquad (10)$$

The shortcomings of Eq. 10 consist in assuming that $z + x = 3$ is a true relation. The writer believes that the relation $z + x = 3.25$ is more nearly correct. From Eq. 10, by inserting his experimentally determined value of z, Scobey obtained Eq. 4. If, however, we take the writer's exponents for V and D, Eq. 9 may be written:

$$H = m\nu^y \frac{V^z}{D^{1.25}} \quad \text{or} \quad H = m\nu^y \frac{V^2}{D^{1.25}} \qquad (11)$$

There is no simple method to determine the value of y. Only the most refined experiments (and there no doubt are many such on record) will serve to give a reliable result. If we should use Scobey's $2 - z$ for y, the value of y in Eq. 11 would be zero if $z = 2$, and the ν term would disappear. This would be true, regardless of whether we started with Eq. 7 or substituted the Mills relation in the form:

$$h_f = \frac{fLV^2}{2D^{1.25}g} \quad \text{......................(12)}$$

It is important to note that Scobey started off with the Darcy form, Eq. 7, and then, having arrived at Eq. 9, changed the exponents to agree with compiled experimental data. This does not appear to be altogether proper.

The variations Scobey obtained from Eq. 4 with respect to temperature (and viscosity) amounted to only 3.2 per cent within the range of 0° to 20°C., which constitutes about the normal span of water temperatures. When engineers were trying to estimate friction characteristics of a given pipe line within 10 per cent, and anticipating possible reductions of even greater magnitude, as the age of a pipe increased, it seemed of little value to pay too much attention to viscosity effects. As pointed out in the original article, however, modern pipe linings do not deteriorate nearly as much as those used formerly, so refinements for viscosity may increase in relative importance. Nevertheless, taking a typical year, water flowing in the Wanaque conduit (which was one of those tested and reported on) varied in temperature from 1° to 19.2°C. According to Scobey's table, this would result in a maximum variation of 2.9 per cent because of change in viscosity. It is no secret that most designing engineers would be infinitely pleased to be able to feel justified in making a correction of that order.

Kalinske (9) suggested a rather unique method of solving pipe flow problems by employing certain parameters. The objections to his method are: (1) that the Darcy formula was used (although any other could be substituted); (2) that the curves were based on tests of cast-iron pipe not typical of present-day products; and (3) that no example or solution was given to show the practicing engineer how readily to use the method suggested.

Rhodes (10) considered that both the Reynolds and Froude numbers should be taken into account. By dimensional analysis, starting with Darcy's formula, he arrived at the equation:

$$h = kLF^{-2e}\mathbf{R}^{-c} \quad \text{......................(13)}$$

where all the terms except F (Froude number) are similar to others com-

monly used. F is represented by $\frac{V}{\sqrt{gD}}$. Assuming $e = -1$, Eq. 13 would become:

$$h = 2k \frac{L}{D} \frac{V^2}{2g} \mathbf{R}^{-e} \qquad (14)$$

Rhodes stated that e did not generally equal -1 in experiments. By using an approximation between certain empirical formulas he obtained:

$$h = 2k \frac{L}{D} \frac{V^2}{2g} \frac{F^{0.04}}{\mathbf{R}^{0.19}} \qquad (15)$$

This formula is subject to the same objection as all formulas based on the Darcy form, since all recent experimental data indicate that the exponent of D should be greater than unity. The use of the Froude number, based as it is on the square root of the expression $\frac{V^2}{gD}$, presupposes that the Darcy relation is correct. It had previously been stated by Rouse (5) that Froude's number "refers to flow with a free surface" and "has no relationship whatever with the inner mechanism of confined flow." Until such authorities on hydromechanics agree, there is little point for the practicing engineer to give much thought to the use of some of these terms.

In the writer's opinion, the contribution of Rouse is one of the best of the more recent explanations and Gavett does well to predicate his study on such a solid foundation. Two important statements by Rouse are pertinent. The first, referring to the letter L in Eq. 5, says:

"The length parameter, L, may have any value, characteristic of the flow, which the investigator may care to select, so long as he is consistent in its use throughout the investigation. Obviously, the characteristic length which he selects will determine the final numerical magnitude of the Reynolds number for a given set of conditions . . . for purposes of uniformity, it is customary, in pipe studies, to use the diameter of the pipe as the length factor."

Referring to the exponential formula for H equated to V and D, with the exponent of V given as n, Rouse says:

"Thus, flow through an absolutely smooth pipe—which may never be realized—would probably become less and less dependent upon the Reynolds number, as the latter increased, attaining complete independence ($n = 2$), however, only when $\mathbf{R}$ became infinitely great."

Assuming, for the moment, that it is correct to use Eq. 6, then at a temperature of 15°C. and a normal design velocity of 4 fps., the Reynolds number for the lower limit of large diameter pipes originally proposed by

the writer (36 in.) would be 973,000 and that of the largest pipe for which complete experimental data are given (74 in.) would be 2,005,000. According to the preceding quotation from Rouse, pipes of such magnitude are approaching the condition where, with the smooth pipes now obtainable, an exponent of 2 for V would be closely approached. This, of course, bears out the suggestion made in the original article that the $\frac{V^2}{2g}$ term is indicative of falling bodies, and that an infinitely large and smooth pipe would tend to create such a condition. Certainly some of the large smooth conduits of today, involving Reynolds numbers of 5,000,000 or more, approach ideal conditions so closely that the error involved in assuming $n = 2$ is negligible compared to other intangibles.

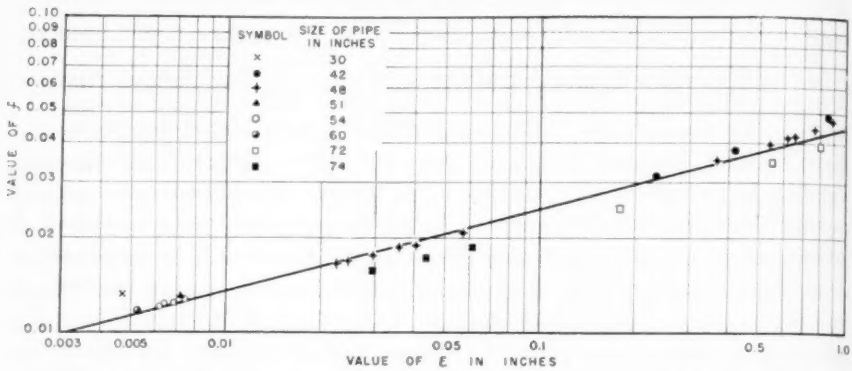


FIG. 3. Relation of Nikuradse's ϵ and Darcy's f (values of ϵ and f from Table 2 in Gavett's discussion)

Perhaps the investigations of losses in bends that have been carried on in detail in recent years will serve to permit the practicing engineer to make corrections in design so that use of other refinements in the future will be justified.

Rouse pointed out that the equation by Nikuradse, expressing the relationship of roughness to friction factor in the form (where r_0 = radius of pipe and ϵ = radial dimension of roughness particles):

$$\frac{1}{\sqrt{f}} - 2 \log_{10} \frac{r_0}{\epsilon} = 1.74 \qquad (16)$$

applied to the zone of turbulence only, and "may be expected to apply generally only in the event that the roughness in question is geometrically similar to that of the sand coatings in Nikuradse's investigation." Since no such tests have been made on pipes operating under the exact conditions of those in New Jersey, Gavett has at least established a basis of

comparison by computing the value of ϵ for various recorded measurements. Plotting Gavett's results for f and ϵ, as shown in Fig. 3 results in a graph that is informative. It illustrates the wide zone between smooth and rough pipe and indicates that the value of f probably never reaches zero regardless of the fact that ϵ may closely approach zero. This same conclusion may be reached both by analyzing the formula used and by interpreting some of the results given by others. Probably the effect of internal friction or turbulence would account for this condition. Rouse gives this impression in some of his well-conceived explanations.

It is not the purpose of the writer to quote at length, but some of Rouse's remarks are so important that they bear repetition. At one point (5, p. 488) he said, "for smooth pipes the term for average viscous shear may be omitted entirely without introducing noticeable error. . . . In the case of rough pipes in the range of constant f, the turbulent action is so excessive that viscous resistance as a function of the mean velocity gradient is completely negligible in all parts of the flow. Thus, the Boussinesq concept of purely turbulent resistance in the central regions of flow is practically realized throughout the realm of high Reynolds' numbers for smooth and rough pipes alike." This statement seems to confirm the judgment of the writer in confining these studies primarily to large diameter pipes, and in neglecting consideration of viscosity. Mills differed from Rouse in saying that a disturbed flow, not laminar, occurred near the pipe walls.

Rouse commented particularly (5, p. 502) on the shortcomings of the term ϵ as given in the equation determined by Nikuradse, but suggested that the term ϵ might be of some relative value after all. Gavett evidently had this in mind in making up his table. The writer has tried to correlate these ideas by plotting two curves, both based on actual full-scale observations recorded in the original article. Following, to some extent, the grouping used by Gavett, values for $\frac{1}{\sqrt{F_m}}$ and $\mathbf{R}\sqrt{F_m}$ were computed and plotted in a manner similar to that used by Rouse. The results were disappointing as was indicated by Rouse in pointing out the possible shortcomings of such a plotting. Next the values of $\frac{r_0}{\epsilon}$ were calculated and plotted, again in a manner similar to that of Rouse. The results are shown in Fig. 4, which indicates the relative value of ϵ that can be assigned to widely diversified commercial pipes with some hope of comparison, if the Nikuradse formula is accepted. There is still a possible criticism of basing all this on a value f from the Darcy type formula, but the relative values to be gained may make it worth the effort.

Computed values of ϵ (radial dimension of roughness particles) indicated about 0.7 in. for Pequannock pipes. Actual observations showed tubercles "frequently an inch in height."

Recent Developments

For some reason, it is difficult to find any graphical presentation of the Reynolds number. In Fig. 1, Gavett has presented such a graph in excellent fashion and has superimposed the lower limits of the turbulent zone, i.e., the upper limit of the critical zone, by means of the $\frac{r_0}{\epsilon}$ values (in respect to **R**) obtained from the Rouse paper. Points plotted for Mills' determinations for limits of laminar flow show a remarkable consistency at **R** = 2,000.

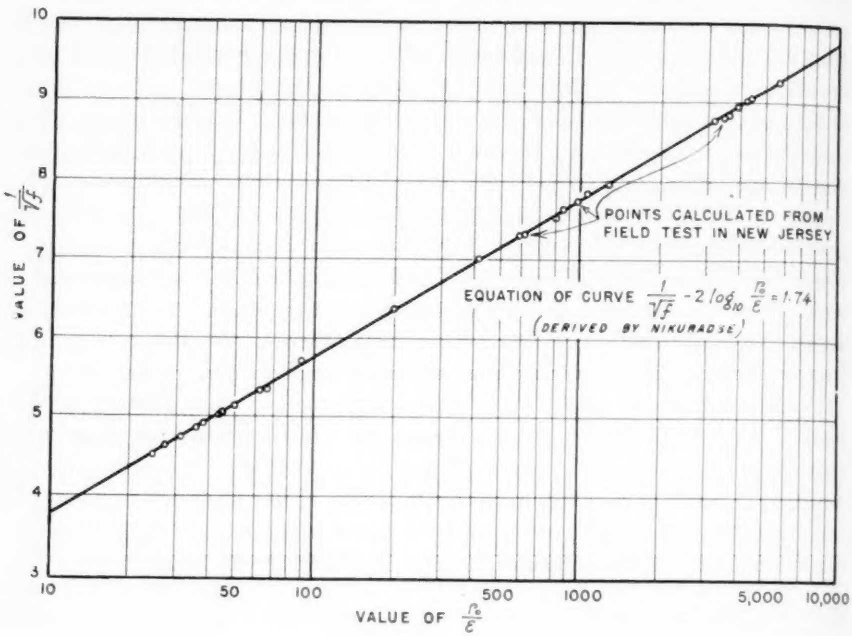


FIG. 4. Relation of Nikuradse's $\frac{r_0}{\epsilon}$ and Darcy's $\frac{1}{\sqrt{f}}$

Another most useful curve is Gavett's Fig. 2 which shows that, for velocities within the range of normal design, the original Mills formula is sufficiently straight to approximate an exponential form. Mills indicated, however, that, in practical design, the linear form of V may often be omitted and only the square term used.

As a general comment on the subject, the remarks by Von Kármán in his discussion of the Rouse paper are in a class by themselves, and anyone who proposes to plunge boldly headlong one way or the other is advised to read the $1\frac{1}{2}$ pages so aptly stated by that author. The writer does not

wholly agree with Von Kármán, however, that pipe lines have been found to yield results within 3 to 5 per cent of predictions. Certainly experiences in New Jersey, under the leadership of many of the best known hydraulic engineers of the country, do not bear out that contention. Recent information at hand indicates clearly that at least one other section of the country has had the same difficulty.

Since the original article was written, Kalinske's paper on turbulence (11) has been published and Kennedy (12) has shown a graphical solution of the relation of **R** to n and f. Both of these have their place, but neither has changed the conclusions originally reached by the writer.

Before concluding, it might be well to point out that many pipe flow diagrams cover ranges from small diameters, such as 2 in., up to large diameters of perhaps 20 ft. If the Reynolds number expresses a true relation, then similitude of action by the two pipes would only exist if the velocities were in inverse relation to their diameters. This is equivalent to saying that an experimental pipe 12 in. in diameter could have a velocity of 40 fps. to be compared with a proposed one 10 ft. in diameter having a velocity of 4 fps. Such a condition, if strictly true, may be of great benefit, but caution is urged that the use of astronomical figures for velocities, even if only in theory, is not conducive to thorough understanding by the practicing engineer. It therefore becomes desirable to use moderation in establishing limits for the model and its prototype.

Conclusions

It may be noted that neither here nor in the original writing have any new formulas been introduced. The hydraulic profession has been cursed with an oversupply, and it was felt that a more useful purpose could be served by attempting to indicate those which may be readily employed with some degree of assurance.

This is not a hymn of hate against the fluid mechanicians or mathematicians, nor an unqualified advocacy of the empiricists. Rather, the writer has been forcibly thrown into a controversial whirlpool of conflicting opinions or methods of calculating pipe line capacities and has attempted to set down a series of observations that will enable others to reach rational conclusions. Furthermore, it was desired to establish a reasonably easy and correct method, empirical though it may be, by which hundreds and perhaps thousands of engineers who have such problems may hope to cope with them with a reasonable degree of assurance.

So far no one has convinced the writer that any of the modern teachings of fluid mechanics will enable the engineer to obtain any more accurate or reliable results in design than is now obtainable by use of the Mills formula. In fact, it appears that this simple formula is not only supported empiri-

cally but also by the findings of hydromechanics for the range of sizes and velocities covered in the writer's paper. This should give comfort to those engineers who might be concerned that present-day hydraulic theory would eliminate simple methods of computing pipe flow. For those interested in the causes of pipe friction, a study of hydromechanics will prove fascinating, and where special problems are encountered, such as flows in small pipes and tubes, flows of viscous fluids, tests of models, etc., the help of hydromechanics will be essential. Both Mr. Gavett and the writer feel that the study of fluid mechanics is one of unquestionable value. The extent of this value is not yet known.

Important contributions to the general subject have been presented recently by Ellwood (13) and Leitner (14). No discussion on the subject would be complete without drawing attention to the work and teachings of Professor Boris A. Bakhmeteff (15).

Discussion by *Richard Hazen*.* Mr. Capen has made available new data on friction losses in large pipe lines. His paper covers two subjects—friction coefficients and formulas for estimating the head losses in pipes. There can be little quarrel with his conclusions regarding the effect of age and water quality on friction coefficients of old and modern pipes. The feasibility of restoring the carrying capacity of old pipes by cleaning and lining has been well established.

Much of the paper deals with the exponent to be applied to the velocity term in friction loss formulas. The limited data presented indicate that a velocity exponent of 2.0 yields more consistent friction coefficients than the lower exponents of the Scobey and Williams-Hazen formulas. In view of the divergent results obtained in the numerous investigations that have been made in the past, these results are not surprising. There is question, however, as to the propriety of concluding from these results that the exponent of 2.0 is the proper one for pipes smaller than those studied.

As a practical matter the value of the velocity exponent within reasonable limits is of little importance. Figure 12 of the original Capen paper indicates this. In the range of normal velocities, e.g., between 2 and 6 fps., the maximum variation in head loss under various formulas is about 10 per cent. The greatest accuracy possible is, of course, desirable, but, except in unusual cases, a variation of this magnitude will have little effect.

The tendency toward higher coefficients at low velocities with any of the formulas considered is shown in Capen's Fig. 13. If coefficients obtained at very low velocities are used in predicting head losses at high velocities, trouble may result from inadequate capacity. From the data

* Assoc. Engr. with Malcolm Pirnie, Cons. Engr., New York.

given, it appears that the Mills formula would yield more conservative results in such a case.

Except for the fact that it is generally easier to raise a number to the second power instead of to the 1.85 or 1.90 power, the Mills formula is no simpler to apply than the other exponential formulas. Tables and charts are available for the solution of practically all of the exponential formulas, and the only difference in the charts lies in small variations in the slope of the lines. The term H, head loss per 1,000 ft., has been used instead of slope as in the Williams-Hazen tables since their publication in 1905.

Mr. Gavett's discussion and the subsequent reply by Mr. Capen have brought up an entirely new subject. The writer does not have an opportunity at the present to go into the more theoretical aspects of the matter, and will limit his comments to one or two general matters.

In the normal course of affairs the water works man does not have to worry about the Reynolds number. As long as the velocity is fairly high in a pipe, the flow will be essentially turbulent, and the effect of changes in Reynolds number can be neglected. In Gavett's Fig. 1, it is shown that a velocity of 1 fps. in a 24-inch pipe gives a Reynolds number of 170,000; and a velocity of 2 fps. gives $\mathbf{R}$ = 330,000. These values are well beyond the transition zone between laminar and turbulent flow, and, except possibly in the case of very smooth pipes, a change in Reynolds number in this range will have little effect on the friction coefficient. Furthermore, pipe sizes are usually selected for peak conditions of flow, with velocities of 4 fps. or more. The Reynolds number is essential for a proper understanding of pipe friction, but it can ordinarily be neglected in the practical application of pipe flow formulas.

Mr. Capen has plotted the values of ϵ (radial dimension of roughness particles) against f (friction factor) in Fig. 4. Since the values of ϵ were calculated from the values of f by means of Nikuradse's formula, however, the points obviously must fall on the curve. The points of Fig. 3 can be connected by a series of straight lines, one for each diameter of pipe. These applications of field data should not be mistaken as a corroboration of Nikuradse's formula, because the formula itself was used in determining one of the unknowns.

Author's Reply—***Charles H. Capen.*** It might easily be supposed that Mr. Hazen, in support of the well known formula developed by his father, Allen Hazen, and Gardner S. Williams, would look askance at any effort to upset that long standing and universally applied equation. Such is not the case. As if further to testify to the attitude exhibited in the preceding remarks, Mr. Hazen, at a recent colloquium on flood control, commented, in reference to the flood frequency data published by his father, that such

criteria were intended largely for comparative purposes and were in no sense to be considered as establishing an incontestable theory. Such admissions are all too uncommon among engineers.

The crux of the situation is the fact that Mr. Hazen points out, in reference to an exponent for velocity, that it is easier to raise a number to the second power than to a power of 1.85 or 1.90, as required with the old exponential formulas. If, as the writer believes, the second power is more accurate as well, it should not only be used but should receive preference, within reasonable limitations, over any odd value.

Comments by Hazen regarding laminar and turbulent flow and velocities are, of course, incontestable. The real significance of the Reynolds number is its value in predicting flows in large pipes by experiments on small ones. Gavett has rendered a real service in pointing out this significance in a way that is far more understandable than most literature on the subject. The writer has merely supplemented this information with a view toward giving, within one discussion, as brief a digest of the subject as may be considered within the reasonable scope of inquiry of any water works man who may have a desire to acquaint himself with the fundamental formulas and reasoning involved.

The writer owes Mr. Hazen an apology in not submitting to him the final curve for Fig. 3, showing the relation of ϵ and f. The curve which accompanies this discussion shows clearly that his comments regarding the fact that a straight line can be drawn for each diameter of pipe are well taken. The curve actually drawn was intended to represent merely a conglomerate median that would approximately illustrate the average conditions in large pipes of between 4 and 6 ft. in diameter.

The real test of the writer's statement regarding the validity of the Nikuradse formula is the fact that ϵ (radial dimension of roughness particles) was calculated to equal 0.7 for certain tests on the Pequannock pipes. The writer actually crawled through these pipes immediately following some of the tests and prior to the cleaning and relining, and reported that tubercles "up to perhaps $1\frac{1}{2}$ in. in diameter, and frequently 1 in. in height, existed in large quantities." If the mean of diameter and height of the tubercles is taken to be 1.25 in., the figure of $\epsilon \times 2$, or 1.4 in., for diameter, as obtained by solving the Nikuradse formula, is sufficiently close, at least for comparative purposes, to render, for perhaps the first time, a practical substantiation of that theory. This comparison has been made possible by the excellent presentation of the subject by Mr. Gavett, whose comments, together with those of Professor Hedberg and Mr. Hazen, are greatly appreciated.

In closing this discussion, the writer would like to reaffirm his belief in the original Mills formula and his belief that the modified form, as pre-

sented, will solve problems of flow in large pipe as accurately as any other method. All data available tend to prove that such is the case; and unless and until someone presents evidence to the contrary, the writer will continue to hold to this belief.

References

1. GIBSON, A. H. *Hydraulics and Its Applications*. D. Van Nostrand, New York (3rd ed., 1925).
2. KING, H. W. *Handbook of Hydraulics*. McGraw-Hill, New York (3rd ed., 1939).
3. MILLS, HIRAM F. *Flow of Water in Pipes*. Am. Acad. Arts & Sci., Boston (1923).
4. SWINDIN, NORMAN. *Modern Theory and Practice of Pumping*. Benn Bros., London (1924).
5. ROUSE, HUNTER. Modern Conceptions of the Mechanics of Fluid Turbulence. Trans. A.S.C.E., **102:** 463 (1937).
6. CRAIG, EDWARD M. Theory of Similitude and the Use of Models. Delaware Wtr. Supply News, **2:** 77 (1939).
7. REED, J. O. AND GUTHE, K. E. *College Physics*. Macmillan, New York (1911).
8. SCOBEY, FRED C. The Flow of Water in Riveted Steel and Analogous Pipes. U.S. Dept. Agric., Bul. 150 (1930).
9. KALINSKE, A. A. Solving Pipe Flow Problems With Dimensionless Numbers. Eng. News-Rec., **123:** 23 (1939).
10. RHODES, LELAND S. A New Pipe Formula. Eng. News-Rec., **125:** 213 (1940).
11. KALINSKE, A. A. Relation of the Statistical Theory of Turbulence to Hydraulics. Trans. A.S.C.E., **105:** 1547 (1940).
12. KENNEDY, ROBERT E. Relation of Reynolds' Number **R** to Manning's *n*. Civ. Eng., **11:** 111 (1941).
13. ELLWOOD, ARTHUR. An Engineer's Approach to Fluid Mechanics. Eng. News-Rec., **127:** 505 (1941).
14. LEITNER, LEOPOLD. Model Tests of the Mixing Channels of the Coagulating Plant at Shafts 17. Delaware Wtr. Supply News, **4:** 353, 357 (1941).
15. BAKHMETEFF, BORIS A. *The Mechanics of Turbulent Flow*. Princeton Univ. Press (1936).

Water Main Extension Policies in Wisconsin

By P. A. Reynolds

IN GENERAL, the growth of a water system and the expenditures required parallel the growth of the community served. The first essential of a smoothly functioning policy of main extension construction to take care of this growth is the formulation of a comprehensive policy covering the requirements for both the near and the more distant future for both urban and suburban districts.

Most water main extensions involve supplying two major classes of service—fire protection and general. In a few cases the extension must also provide for resale service, but since this is relatively infrequent only the two major classes will be considered in this paper.

It has been fairly well established in Wisconsin that the cost of extending mains upon which fire hydrants are placed should be apportioned between fire and general service. Detailed investigations have indicated that from 10 to 70 per cent of the cost of mains has been assigned to fire protection service.

Many attempts have been made to work out an extension policy that will be non-discriminatory. The lack of a definite, adequate and reasonable policy in some municipal utilities in Wisconsin has caused not only the utilities and the property owners desiring service, but the Public Service Commission as well, a great deal of trouble in ironing out specific requests for service.

A property owner anywhere within the corporate limits of a municipality should be able to get water service. As a general proposition, however, there are several main extension policies which can be followed and some of them, experience shows, are inequitable in specific instances. For this reason it is desirable that a utility have a combination rule or rules to take care of every contingency. Experience has indicated that some of the larger, but more of the smaller, municipal water utilities still persist in trying to operate without immediate, reliable and adequate rules. This

A paper presented on October 7, 1941, at the Wisconsin Section Meeting, Racine, Wis., by P. A. Reynolds, Rate Analyst, Public Service Com., Madison, Wis.

discussion, therefore, will relate to policies of extending distribution mains only, rather than attempting to cover the problem as it relates to transmission and feeder mains.

Extension Financing Policies

Extension policies are based upon different methods of financing the cost of extensions, as follows:

1. Special assessments on property abutting on the mains.
2. Utility investment through direct appropriations from the city general fund or through appropriations of utility surplus earnings and assets, offsetting the depreciation reserve.
3. Utility financing the equivalent of average customer density footage, the customer paying the balance.
4. Customer financing the entire cost.
5. Utility advancing funds to be reimbursed by revenues from the extension, which are to be used exclusively to pay off the indebtedness incurred.
6. Governmental grant, with either the utility or the customer contributing a part of the cost.

The assessing of property for benefits and damages attained from water main installation costs has been followed in a great many Wisconsin cities in the past, and its application is fairly well known. In a modification of the applicable law (Laws of 1937 (Wis.), Ch. 319, Sec. 66.06 (10) (d)), however, the following statement was made:

"Where in any municipality water mains have been installed or extended and the cost thereof has been in some instances assessed against the abutting owners and in other instances paid by the municipality or any utility therein, notwithstanding the provisions of Sec. 62.19 it may be provided by the governing body of such municipality that all persons who paid any such assessment against any lot or parcel of land may be reimbursed the amount of such assessment regardless of when such assessment was made or paid.

"Such reimbursement may be made from such funds or earnings of said municipal utility or from such funds of the municipality as the governing body may determine."

The question has been raised informally several times as to whether or not two different methods of financing the laying of water mains could be used for thickly and thinly populated areas of a city. The legal staff of the Public Service Commission has indicated that Sec. 62.19, Statutes, applies to all cities, but that the provisions thereof are modified to a certain extent by Sec. 62.195 with respect to cities of the second, third, or fourth

classes. In any of these last three classes the "Common Council" may, by ordinance, provide that the cost of installing, constructing or laying water mains "shall be charged in whole or in part to the property benefited thereby, and to make an assessment against such property in such manner as such council or village board may determine."

It appears that this clearly contemplates a provision for the exercise of reasonable discretion on the part of the "Common Council" with respect to how much of an assessment shall be made against abutting property. It does not appear that the provisions of the two sections of the statutes just referred to are in any way modified by the provisions of the amendment cited above. The provisions of that chapter apply and were intended to apply to inequities which have occurred in the past and were not intended to constitute or provide any rule respecting the defrayment of the cost of laying water mains by abutting property owners.

In view of the foregoing considerations, it appears that an ordinance providing for an assessment of a particular part of the cost of laying water mains in thickly populated areas and for a different part of the cost of laying such mains in thinly populated areas would be valid provided that the provisions of such ordinance were not in themselves so unreasonable as to be set aside by the commission or the courts. In other words, it is believed to be lawful to provide different provisions for different areas to be served, but the difference itself must be such as to remain within the bounds of reason.

During the past few years many cities and villages have made main extensions, the greater portion of the labor cost of which has been carried through government grant. The labor cost per foot of 6-in. main has varied widely. Several cases were noted, where, under practically similar physical conditions, this cost varied from $0.55 to $1.64 per foot. If the 55-cent average appeared reasonable for labor cost on a contract basis, then the excess cost per foot, due to the character of the employment, should not be set up on the utility books. In the event that it was charged to fixed capital, the utility would have to continue to depreciate this excess investment and accrue taxes thereon, distorting normal operation.

Effect of the National Defense Program

It is obvious that the national emergency has affected and will continue to affect the extension of water mains because of shortages in cast-iron pipe, valves and fittings. Many projects may turn out to be extensions into territory which will be needed only temporarily for workers or operations of defense industries.

In the public interest there can be no moratorium on the responsibilities of either the utilities or of the Public Service Commission to promote extension of mains under as favorable and reasonable terms as conditions

may warrant. It would seem clear that investments in main extensions for emergency undertakings may have to be handled somewhat differently than would be the case under normal conditions. Possibly some of these extensions may have a useful life limited to the emergency period and this fact may necessitate a higher rate of depreciation than on normal main extensions. The public interest, it would seem, would not justify any attempt to depreciate completely, during the emergency, the investment in such facilities which will have a continuing use after the emergency is ended.

Wisconsin Ordinances and Rules

From the files of the commission several main extension policies have been noted specifically and abstracts or briefs prepared to illustrate one or more of the bases enumerated above.

Special Assessment and Customer Financing

The first plan outlines a combination of special assessment and customer financing, covering policies 1 and 4 as listed above.

"Extensions of water mains forming a part of, and connected with, the city-owned water works will be laid as heretofore under the special assessment statute or under a customer financing plan as set forth below:

"Where mains are required to be laid ahead of paving due to municipal requirements or upon petition of a majority of the owners of the taxable frontage on any street contiguous to a street on which water main is already laid, the Board will proceed . . . as follows:

"The Board shall assess against the several lots, parts of lots, or parcels of land which front upon the proposed line of water main, or which may be contiguous to and used in connection with any such lot or parcel of land, such sum as the Board shall determine such lot or parcel of land will be specially benefited thereby, not exceeding one-half of the cost of furnishing and laying a water main of not more than six inches.

"When the signatures of a sufficient number of the property owners cannot be secured to further the extension of mains by special assessment, then such extension will be made by the city only if the applicant or applicants for the water main extension will advance to the city the estimated cost of the extension.

"Each additional customer connected with the extension will be required to advance to the city a connection charge which will be so determined or adjusted with the connection of each new consumer or group of consumers as to reflect the average investment which each has in the extension, to the end that at all times prior to final refund, all consumers on the extension have a like sum advanced. In other words, the new customer connecting will pay a connection charge equal to the average investment in the exten-

sion before the new customer is added, which connection charge will be refunded *pro rata* to all customers on the extension, including the new customer."

Special Assessment and Governmental Grant

The second plan, which follows, was intended to take care of government aid projects, principally in a community where mains had been extended originally by assessing abutting property. This is a combination of policies 1 and 6.

Main Extensions Without Governmental Aid: Water mains will be extended to supply service to new customers in accordance with the provisions of the special assessment statutes. Owners of abutting property, however, will be assessed the cost of laying the main, as distinct and separate from the cost of pipe and materials which will be borne by the utility.

Main Extensions With Governmental Aid: "In cases where mains are constructed with governmental aid, the assessment procedure shall be waived and in lieu thereof each new customer who shall henceforth connect to such main shall be charged as a condition of service a connection charge equivalent to 40 cents per foot of such main abutting the property owned by such new customer.

"A customer who already receives service by means of a privately constructed service connection to existing mains, shall be charged, as a condition of connection to a main financed with government aid, a connection charge equivalent to 20 cents per foot of such main abutting the property owned by such customer*.

"In determining the connection charge corner lots shall be given the same consideration as is given under the assessment basis followed in regular main extensions.

"A new customer whose property does not abut the main, who can be served by a long service line, shall be charged, as a condition of service, a connection or tap charge of $17.50, which shall be credited towards any assessment or connection charge subsequently determined in the event a main is constructed that abuts property owned by such customer."

Combination Policy

Sections 1 and 2 of the group of extension rules presented below have been used by many small village- and city-owned water utilities after the

---

* The charges corresponding to the 40 and 20 cents cited here should be determined from the average amount which has been paid by the customers under the arrangement followed in the past. There should be some reasonable relationship to the average material cost per foot.

original installation has been in service for many years. These two sections, together with the optional section have been in use in a city of 60,000 population for about seventeen years with very satisfactory results.

1. *Extension of Small Water Mains in Outlying Districts Other Than for Fire Protection Service (Size of Pipe Not Less Than 2 In.)*: "The utility will extend and finance water mains not to exceed 100 ft. for each customer along the line of such extension, measurement beginning at the line of the cross street. Where the extension desired is in excess of 100 ft. per customer, then such extension will be made by the utility after the applicant or applicants for the water main extension have advanced to the utility the cost of such extension in excess of the free limit. The size and kind of materials will be specified by the utility.

"When new consumers are connected to a water main that was paid for in part by customers the utility will refund to the party or parties making the advance, not including the new customer, the cost of a 100-ft. front extension for each customer. The new customer connecting, however, shall pay a connection charge equal to the average investment in the extension before the new customer is added, but after the adjustment due to the refund by the utility because of new connection, which connection charge will be refunded *pro rata* to all customers on the extension, including the new customer."

2. *Extension of 4- or 6-In. Water Main Where Fire Protection Service is Supplied*: "The utility will extend and finance water mains 4 in. in size or larger under the same conditions as pertain to small sizes, except that the free limit shall not exceed 50 ft. per customer.

"The cost of extensions of mains 4 in. in diameter or larger on which fire hydrants are placed will be apportioned between the two classes of service supplied, namely, fire protection service and general service to consumers on the basis of 50 per cent to each, to the end that in such cases the advancement or the guaranty, whichever plan is followed, will be required only as to 50 per cent of the excess of cost after allowing the free limit for each consumer."

3. *Optional Extension Rule Applicable to All Sizes of Pipe*: "The applicant or applicants for water service will subscribe and file with the city on the city's form a written guaranty to pay annually, in addition to the proper and lawful charges for water used, the applicant's share of the sum of six dollars ($6.00) for each one hundred dollars ($100.00) of water main extension cost in excess of the free limit credit for each consumer, prorated to each on the basis of the number of consumers connected, or presently to connect, with the extension. All sums owing to the city under such guaranty and overdue are declared to be delinquent charges for water consumption for all the purposes of the Wisconsin Statutes, including the lien rights against the realty and the guaranty shall so recite. The city will

readjust the *pro rata* share of each consumer connecting with an extension as additional new consumers connect therewith so that each will continue to have the same charge until such time as there is a consumer for each free limit credit, when all the guaranties will lapse."

Extensions Outside Corporate Limits

Rules covering main extensions outside the corporate limits of a city owning its water utility usually require that the entire cost be financed by the property owners or other parties interested in getting the service. The following rules have been made effective for this purpose.

"Water service will be furnished to applicants living outside the city limits only when such service can be furnished without adversely affecting the service inside of the city, and the Board of Water Commissioners must approve the application before service will be given.

"Water mains laid outside the city limits shall be under the supervision and specifications of the water department.

"If such main is laid at the instigation of the water department and principally for its own use as a transmission main, property owners abutting on such main who desire service shall pay an assessment determined in accordance with the provisions of Section 62.19, Wisconsin Statutes. That is, this special main assessment shall be such sum as the Board shall determine each lot or parcel of land will be specially benefited by the installation, not exceeding one-half of the cost of furnishing and laying a water main of not more than 6 in.

"If a water main 6 in. in size, or smaller, is laid or extended at the request of a property owner, or owners, and is not a transmission or feeder main, it will be considered a private main and the entire cost of installation shall be borne by the property owner, or owners, desiring the service.

"When new customers desire connection to a so-called private water main, the new customer shall make a contribution and refunds shall be made to existing customers so that the contributions of all will be equalized. The water department will keep a separate record of each individual private water main extension.

"Where a further extension of a private main is desired, the estimated cost of the new extension will be advanced to the water department by the new customer to be benefited (adjustments to be made with each customer when the exact cost is determined). The customer, or customers, shall also be assessed, in addition to the cost of the special construction requirement to serve them, one connection charge equal to the average investment in the main extension to which this new main is attached. This latter connection charge will be refunded by the water department as provided in the paragraph immediately preceding this.

"The applicant agrees that if, and when, the property, or any part thereof, so supplied becomes a part of the city the ownership of the water main laying within the property so affected shall technically pass to the city as a water utility without any compensation except that, if the main benefits property which has not previously borne a portion of the cost, this property shall be assessed and the proceeds therefrom shall be refunded to the other property owners *pro rata* as provided above."

Utility-Financed Extensions

There has been no discussion of the financing of extension through funds raised by the issuance of mortgage bonds on the utility, or from general fund advances as noted in extension policy 2 as listed. Such extensions do not usually create the problem a customer-financed one does. The fixed capital on which the utility may earn a return is increased on a utility-financed extension. Although the investment on main extensions which have been financed entirely, or in part, by contributions, is added to the fixed capital account, in Wisconsin it is offset by an account "Contributions in Aid of Construction" for the part assessed to property owners or contributed by Federal authorities. These assessments and contributions are deducted in determining a rate base.

Since 1931 when the public utilities law was modified, the Public Service Commission has original and concurrent jurisdiction with municipalities to require extension of mains. This revision removed the limitation on the power of the commission to act on its own motion to require extensions.

By its general order of October 19, 1933 (docket 2-U-637) the Public Service Commission proposed to secure information respecting proposed construction as materially affected the public interest. Rule IIIa relating to "Transmission and Distribution Mains" states:

"Any installation, construction, replacement, extension, or acquisition of mains in any municipality, in which said utility is legally operating as the only water utility therein, which is estimated to involve gross property additions in excess of 25 per cent of the existing investment in the corresponding class of plant in the same municipality, or in excess of $10,000, whichever is the smaller, provided that advice need not be given of any project of less than $500."

Prior to the enactment of the above rule many instances had been noted where extensions involving several thousand dollars were required to be made at the expense of local utility commissioners due to pressure brought by city councils, one of whose members, for possible political reasons, fostered the proposition. The possibility of forcing water utilities into costly extensions from which little revenue will accrue is lessened under the above general order.

Private Utility Extensions

As an example of the extension rules of privately owned water utilities, the principal sections of the rules and regulations governing the extensions to water distribution systems in Beloit and Ripon, Wis., are given below. It will be noted that, in general, the provisions follow those noted in the previous discussion. Section 9, which provides for the co-operation of the private company and the city, is the result of a legislative enactment making such mutual interests compatible.

Quotations From Beloit and Ripon Rules

SECTION 2. *"Free Limit" Defined*

The "Free Limit" is either "A" or "B," whichever is the greater:

A. The utility will, upon written application, extend its water distribution system to serve a new customer or group of customers providing the extension does not require more than 50 ft. of main per customer.

B. Should an extension require construction in excess of 50 ft. of main per customer, the utility will make the extension without cost to the customer or group of customers making application for service provided the utility's estimated cost of a similar extension of sufficient capacity to serve the applicant or applicants is not greater than four times the utility's estimate of the annual revenues to be derived from the actual extension. Only that portion of the fire protection charge as is derived from the charge of eight cents (8¢) per linear foot of main will be included in the estimate of revenues. (The size of main used in determining the costs herein mentioned shall not be of a less diameter than the minimum-sized main adopted as standard for the particular municipality in which the extension is made.)

The utility will base its estimates of construction costs and annual revenues upon its experiences with similar installations.

SECTION 3. *Extensions Requiring Deposits by Customers*

A. Should a normal extension require construction in excess of the "free limit," as defined in Rule 2 above, the utility will make the extension, provided the customer or group of customers to be served or the municipality, will deposit with the utility in advance an amount equal to the excess of the estimated cost of the extension over the free limit. When the free limit is determined on the basis of 50 ft. of main per customer, the free limit shall be priced at the average cost per foot for the extension.

B. In the event the actual cost of the extension is less than the estimated cost, the utility will refund to the party or parties making the deposit, the amount by which the estimated cost exceeds the actual cost. In no event, however, will the refund exceed the amount deposited as provided for in paragraph 3-A.

A customer making a deposit under these rules is not exempt from the application of the utility's standard rule requiring a deposit to insure prompt payment of monthly bills for service rendered.

SECTION 4. *Construction Costs (Estimated and Actual)*

The utility's estimates of the cost of an extension will include right-of-way costs and all items of materials and labor, including any extraordinary costs occasioned by opening pavements, rock digging and frost—together with allowances thereon for engineering and general office expense—pertaining to the purchase, storage, delivery, and installation of all equipment (excepting a standard meter and a part of the service pipe, as otherwise provided for in Rule 1) necessary to extend adequate service to the customer or customers to be served from the extension; excepting that the costs so determined will not include any costs incurred by the utility in rebuilding or reinforcing any facilities existing at the time when applications for service were made by the customer or group of customers requiring the extension; neither shall the costs billed to the customer or group of customers desiring service, include any charges occasioned by the installation of a water main larger than what would be necessary to meet the customer's or customers' estimated normal requirements, but in no case will computations of costs be based on a main of less diameter than the minimum-sized main adopted as standard (see paragraph 2-B).

SECTION 5. *Extraordinary Investment by Utility*

In all cases where, in the opinion of the utility, its investment in an extension appears extraordinary or unusual, and where extensive rebuilding or repairing of any facilities is necessary to accommodate the customer or group of customers making application for service, the right is reserved to require the customer or group of customers to be served from the extension to execute a contract for a definite period of service, and otherwise to protect the utility against possible losses.

SECTION 6. *Refunds—Additional Customers*

An additional customer on an extension is defined as a customer to whom service can be extended under the "free limit," or at a lesser contribution per customer than is then outstanding on the existing extension.

In all cases where the costs of taking on a new customer or group of customers exceeds the construction costs per customer for the existing extension, the construction necessary to serve the new customer or group of customers will be considered as a new extension.

Should an additional customer or additional customers (as defined above) be added within twenty years to an extension for which there are then outstanding contributions, the contributions of all customers on the extension

shall be recomputed, to determine the contribution to be required of the additional customers, and the refund to the existing customers, in such manner as to equalize all contributions for the extension, past and present.

In estimating a fair share of the cost of the entire extension which the additional customer or customers should assume, the utility will give consideration to classes of service involved, relative consumptions of customers, locations of customers with reference to the original distribution lines and any other facts deemed pertinent.

In the event the parties to whom refunds may be due have contributed different amounts toward the construction costs of an extension, refunds will be made to the parties in proportion to the amounts deposited by them when the extension was promoted.

No refund of a contribution received for an extension will be made after twenty years from the date service was first established on that extension, and in no case will the total refund to a customer exceed the amount contributed by him.

SECTION 7. *Title*

The title to every extension of mains is at all times with the utility. The utility reserves the right at all times to add additional customers to an extension, and to make new extensions to an existing extension, under the provisions of these rules without procuring the consent of any party or parties contributing to the original construction costs, and without incurring any liability for refunding on deposits, except as additional customers may be added as provided for herein.

SECTION 8. *Construction Standards*

All construction in water extensions will conform with the utility's standards of construction, and with the requirements of the Government Regulatory Bodies.

SECTION 9. *Extensions on Order of the Council*

Should an extension requiring deposits, as provided in paragraph numbered three of these rules, be ordered laid by the Common Council of the municipality, pursuant to a contract providing for laying of mains on order of the Common Council under Section 62.19 of the Wisconsin Statutes for 1939, and should the cost of such extension above four times the average annual revenue estimated by the utility be paid by the municipality out of special assessments or otherwise, then the refunds provided in paragraph numbered six of these rules shall be made to the municipality by the utility, and in case such special assessments have been levied, the refunds due the owners of property assessed become the obligation of the municipality.

Methods of Financing Water Main Extensions in California

By Morris S. Jones

IN ESTABLISHING a financial policy for a municipally owned water utility, one of the important considerations is the method of financing water main extensions. To indicate some of the general practices in providing for such extensions, the author proposes, in this paper, to discuss the extension policies of the larger California cities, in which the great increases in population during the past twenty years have necessitated large expenditures for expanding and enlarging water systems.

The largest increases in population have occurred in the Southern California cities. In the twenty years between 1920 and 1940 Los Angeles gained a million new inhabitants and San Diego's population increased from 74,000 to over 200,000. As to how great the increases have been since 1940, because of the defense work centered there, even their own chambers of commerce will not hazard a guess. Other Southern California cities, such as Long Beach and Glendale, have tripled or more than tripled their population in this same period; and cities in the northern and central part of the state have had healthy growth, though not comparable with that of the southern cities.

Information as to the procedure in financing water main extensions was collected from sixteen cities and two municipal water districts. The replies received indicate considerable variation in the plan used, but, in general, the methods can be placed under three classifications:

1. Extensions paid for out of revenue by the city or district.
2. Extensions financed temporarily by deposit from applicant, which is later refunded.
3. Extensions paid for by owners of property benefited.

Included in the first group, where no payment is required from the property owners for main extensions, are the cities of Anaheim, Sacra-

A paper presented on October 23, 1941, at the California Section Meeting, Fresno, Calif., by Morris S. Jones, Chief Engr. and Gen. Mgr., Pasadena Water Dept., Pasadena, Calif.

mento and Fresno. In Anaheim, the need for extension is first determined by the City Council and an appropriation for the cost of the new improvement is made from the general fund. The Water Department is then authorized to proceed with the construction.

In Sacramento, within the city limits, there is no direct charge against the owners of the property benefited. The 4-, 6- and 8-in. distribution mains are financed directly from Water Department revenues. Where larger mains are required, the construction cost is financed by the sale of bonds. Interest and redemption of such bonds are paid from department revenues and not from taxation. In extending service to a new subdivision outside city limits, a contract is made with the owner of the land who normally advances the monies for the mains laid to and through the subdivision. The subdivider is reimbursed as each new consumer is connected to the new main. It is possible for him to recover 100 per cent of his deposit provided the subdivision is completely built up within ten years.

Fresno operates on a similar policy. In general, extensions of water mains are made without charge to supply property within the city limits. All such extensions are made from water revenues. In cases where the estimated immediate revenue from an extension does not seem to warrant the expenditure, however, the applicant is required to deposit with the city the cost of the main, less the cost of the first 100 ft. thereof. Refunds are made on the basis of $100 for each new service attached to the new main. In the area served outside the city, the owner is required to deposit the full cost of the extension. The deposit is then returned on the basis of $75 for each house or store building connected to the main and occupied, payable one-third within 30 days after the date of connection, one-third after one year, and the balance within two years.

Financing by Applicant's Deposit

Under the second classification are grouped the cities that finance main extensions from water revenues, but demand that the applicant deposit the full cost of the installation or guarantee sufficient new business to the department to warrant the capital investment. Deposits are refunded within a term of years, depending upon the number of consumers connected to the new main, or the annual revenue produced. Such procedure is in effect in San Francisco, Long Beach, San Bernardino, Riverside, Santa Barbara and the East Bay and Marin County Municipal Utility Districts.

In San Francisco, the water department will extend its mains without charge a distance of 150 ft., exclusive of street crossings, or more than that distance if the cost of installation does not exceed four times the estimated annual revenue. When the cost of the extension exceeds that amount, a deposit equal to the difference between the cost of the new installation

and four times the estimated annual revenue is required. The department will thereafter refund to the applicant, until the amount of the deposit has been refunded, four times the annual revenues collected from additional permanent consumers connected to the new main.

In Long Beach extensions are made within the city upon the basis of $1 deposit for each linear foot of main, plus $20 per lot for the service connection. No deposit is required if immediate construction is contemplated along three-fourths of the frontage that will be supplied by the new main. Wherever deposits are required, refunds are made for each new permanent service connection on the basis of the total deposit divided by three-fourths of the number of lots that can be served. In the area outside the city, a deposit equal to the actual cost of main and services is required. Refunds are made on the same basis as within the city.

San Bernardino will extend a main 600 ft. without cost to the owner, provided there is a possibility of securing five new active consumers. Where there are less than this number of consumers, a deposit based upon the total cost of the main is required. All of the deposit is returned when the requirement of five consumers to each 600 ft. of main is met.

The Light and Water Department of the city of Riverside is under the control of a Board of Public Utilities. It is the practice of this city to extend water mains without charge up to a distance of 100 ft., to reach a new permanent consumer. Extensions longer than 100 ft. require a deposit which is generally based upon the installation cost of a 4-in. cast-iron main, less the cost of the 100 ft. of free main. This rule applies even though the department may install a larger main to provide for future extensions. A refund of $50 is made for every new consumer attached to the new main within the first five-year period.

Santa Barbara requires the owners of property applying for an extension of a water main to deposit an amount equal to the total cost of the installation. Refunds are made quarterly to the applicant in amounts equal to one-half the total water revenue received from the extension during the preceding three months. If the total amount of the deposit is not returned within ten years, the balance becomes the property of the city.

The East Bay Municipal Utility District furnishes water to Oakland, Berkeley, Alameda, Richmond, and other smaller communities. New regulations governing the procedure for extending water mains became effective September 1, 1941, providing that the district will make main extensions following payment by the applicant of the cost of the installation at specified unit prices. These costs range from $1.25 to $2.50 per foot depending upon the length of main and the type of pavement under which it is laid. A credit of $100 is allowed for each service applied for when the application is made. Whenever additional new services are con-

nected to the new extension, further refunds of $100 each are allowed. If the total revenue received from any service, other than those upon which advanced credit is allowed, exceeds $100 during the first four-year period, the amount over $100 is paid to the applicant as an additional refund.

Main extensions for industrial service which require pipes 8 in. or over in diameter are installed upon payment of the estimated cost of the installation, less an allowance of $150 for each *bona fide* service contracted for. Refunds are based upon the total revenue received from a service during the first four-year period after installation. Any balance of the original deposit, remaining after ten years from the date of the original extension contract, becomes the property of the district.

The Marin Municipal Water District requires a deposit of the estimated cost of the extension before the work is started. Refunds are made on the basis of one-half the revenue accruing from services attached to the new main, until the entire deposit is returned. No refunds are made after ten years from date of contract.

Financing by Owner Benefited

Under the third method of financing main extensions a part or all of the cost of installation is paid by the owners of the property benefited. Main installations are made under assessment proceedings or by contract between the owners and the city. Municipalities which have adopted this procedure in financing extensions are all located in the southern part of the state, and include Los Angeles, Glendale, Burbank, San Diego, Pasadena, South Pasadena, Alhambra and Santa Monica.

The procedure followed in Los Angeles was very fully described by E. F. Dandridge of the Bureau of Water Works & Supply (Jour. A.W.W.A. **33**: 219). Briefly, the regulations governing water service extensions in Los Angeles are:

Extensions of less than 200 ft. from an existing main are made upon payment of 80 cents per front foot of property to be served. The length of pipe used in crossing streets or alleys is not included in the measurement of the extensions. For extensions of more than 200 ft., the city requires the owner to deposit an amount equal to $1.60 per linear foot of main. This deposit minus 80 cents per foot of the property frontage requiring service will be refunded to the payer when street frontage charges are collected by the Bureau from other persons requiring service from the extension. Should the Chief Engineer and General Manager determine that the sale of water from the extension will yield an annual income equal to $12\frac{1}{2}$ per cent of the total investment of installing such extension in excess of 200 ft., the additional amount is not charged to the person

making the original application, but is collected from the owners of other property along the new main at the time water service is requested.

The Los Angeles water bureau requires the payment of $1.60 per linear foot of main for piping new subdivisions plus the charge of service laterals and fire hydrant connections. No refund is made to the subdivider. Mains are installed in industrial tracts on a cost basis. In addition to charges for main extensions, as above outlined, the bureau requires that all owners of property fronting on streets within the city, in which water mains have been laid since August 30, 1931, and who have not heretofore paid a frontage charge, pay 80 cents per front foot, in addition to the regular service charge before water service will be rendered.

Glendale requires that the full cost of any main extensions be deposited with the Public Service Department before main installations are made. The deposit is based upon the cost of the complete installation from the ends of the existing water main across the entire frontage of the applicant. A refund of that portion of the cost of the main benefiting property other than that owned by the applicant is made when the main charge is collected from the other property owners. A retroactive frontage charge of $1 per front foot is also made against all property fronting on a main laid by the city whenever water service is requested, provided such charge has not been previously collected.

Burbank requires that the applicant for a water main extension deposit with the Public Service Department an amount equal to 87 cents per front foot for each side of the street in which the extension is to be laid. Where the applicant does not own all the property benefited by the extension, he receives a refund when the main charge is collected. Under this plan the 7 cents per foot is set aside in a special fund from which is paid the installation of fire hydrants. The remaining 80 cents is used to defray, insofar as it can, the cost of the water main extension. The distance run in crossing streets, alleys, or along the sides of lots is not included in computing the charge to the property owner.

The five cities, San Diego, Pasadena, South Pasadena, Alhambra, and Santa Monica follow the same general procedure in regard to extensions. Property owners are charged the total cost of the extension where the mains laid are not larger than 6 in. in diameter. If larger mains are required, it is the general policy to pay from water revenue the difference between the cost of the 6-in. pipe and the larger main. In some cases, the cost of a 6-in. cast-iron main is included in the proceedings for a street improvement, and the cost charged to the property owners along with the other improvement costs. Most of the water main extensions, however, are made by contract with the owner.

Alhambra assesses the street frontage for all main replacements at the rate of $1 per foot and allows the property owner to pay the charge in monthly payments over a two-year period. San Diego makes a charge for replacements where the old main size is less than 4 in. in diameter. Pasadena and South Pasadena replace old mains, irrespective of size without charge to the property owner.

Summary

Summarizing the various methods used in financing water main extensions then, it is found that three cities make extensions from water revenues without charge to the property owners; seven also make extensions from water revenues, but require a deposit to guarantee that sufficient revenue will accrue from the new main to justify the investment; and eight cities find it expedient to charge all or the greater part of the cost of water main extensions to the property benefited. Opinions differ as to which plan is the most equitable to the consumer. If extensions are financed from revenue, the water rates must be maintained sufficiently high to provide funds for these extensions. In other words, present consumers pay higher rates for water in order to finance a capital investment to serve future consumers. As a matter of fact, the amount of capital ordinarily expended each year for main extensions by the cities which follow this policy is not large enough to affect the rate base materially. Where a large expansion program has been carried on, several municipalities have financed the expenditures from bond issues which were later retired from department revenues. A deposit should be required, as it guards against the making of an unprofitable investment and prevents application from property owners for main extensions that are not actually needed.

The front footage charge or direct assessment method is the procedure followed in the Southern California cities that have had the largest expansion programs. This method allows for immediate financing of any needed extensions without drawing on the utility's cash reserves or necessitating a bond issue. The chief argument in favor of the direct assessment method is that any improvement, which is a local benefit only, should be paid for by the property benefited. This is the general practice in most cities in financing construction of sewers, street paving, and similar improvements.

In conclusion, it may be pointed out that of all the cities contacted, not one believed it was necessary to change its present policy in financing extensions. In a few cases, consideration was being given to raise the amount of the deposit or the direct charge to the property owner more nearly to equal present day prices. In every city listed, its present policy for financing water main extensions has been in effect for many years and appears to be satisfactory to both the utility and consumers.

Problems and Limitations in the Installation of Water Main Extensions to Suburban Areas

By M. B. Whitaker

ONE of the more difficult problems confronting the water works operator of today is the necessity for considering and acting upon the many requests for water service by real estate dealers and individual property owners owning property located beyond corporate limits. Requests of this character have been on the increase during the last decade.

Previous to the 1931–32 depression, the population movement was from the rural to the urban areas; now it is from urban to suburban areas. From 1930 to 1940, the population of Cleveland, Rochester, N.Y., Portland, Me., San Francisco, and other large cities, remained practically stationary inside the city limits, and the adjacent areas increased in population from 10 to 45 per cent.

Before the advent of cheap transportation, water supplies generally served compact, closely built-up areas requiring a minimum of distribution system expense for a maximum number of customers. This condition is rapidly changing so that now water operators find that their cost of investment per customer is steadily increasing from year to year. The requests for suburban water lines originate primarily from real estate operators proposing the development of new subdivisions from individual property owners who have built outside the city, and from local health authorities who are desirous of cleaning up some health menace adjacent to the city proper, that may be eliminated by supplying pure water. The health authorities feel that a case of typhoid fever just outside the city is just as dangerous as one within city limits. In the consideration of this type and character of requests for suburban water service, many factors have to be taken into account before the installation of the water line. Principal among these are capital cost, operating cost, depreciation and anticipated revenue.

The municipal water supplies in Kentucky and Tennessee are not subject to the jurisdiction of the state utilities commission, and are generally

---

A paper presented on October 28, 1941, at the Kentucky-Tennessee Section Meeting, Nashville, Tenn., by M. B. Whitaker, Supt., Water Bureau, Knoxville.

handled and supervised by the local governing body. The water works operator has the responsibility of approving or disapproving any water main extension. Water works owned by private utilities must follow definite limitations and procedures in considering new work. This discussion, therefore, will deal principally with municipal supplies.

The municipal operator generally is a local man, familiar with the trend of building or population shift in his community, who can analyze to a reasonable degree the factors entering into a water main extension necessary for the applicant's present and future needs. His judgment of course, is not infallible, and if he errs it is generally in favor of the water works.

The capital cost of suburban water lines is usually borne by the applicant for water service. The officials of the municipalities usually act on the basis that such an applicant has no liability to the corporation for bonds issued for the purpose of building a water supply or other responsibilities of the citizens living within a municipal corporation. For this reason, it is standard practice to require that the mains be paid for by the applicant, and that the water rate or revenues for service through these mains be greater than that to the citizens within the corporation. If the suburban water lines installed under such conditions become an asset to the water works, however, refunds of the capital cost are usually made.

Customarily refunds are made by returning a certain percentage of the revenue derived from these lines, or a certain fixed amount for each tap, until all or part of the capital cost has been returned to the party originally contributing it. This method insures the water works against any financial risk other than the increased cost of maintenance occasioned by the additional footage installed in the distribution system. If the judgment of the operator is good, he will require that the main installed be large enough to serve the particular area for many years.

The capital cost of the extension is only a part of the potential cost to the water works. Items of pumping station capacity, force mains, reservoirs, and purification work must be considered, or, inevitably, the water works will be faced with the necessity of increasing water rates. These items must be investigated carefully and a definite amount of revenue collected for them in addition to that collected to cover the capital cost of installation. The operator must not lose sight of the fact that for each new customer an additional load is placed on the plant and supply works.

A quick method by which the operator can determine if he is on safe financial ground, is to find the amount of capital investment for each revenue dollar in his present system and, then, to make sure that that rate of investment is not exceeded for new work. In this way he can ascertain that he will receive at least as much revenue per unit cost from the extension as he does from the original system. In using this method of calculation,

the operator must keep in mind that new extensions will probably cost more to maintain over a period of years, as they will be a greater distance from the operating headquarters than the present mains.

Extension Policy at Knoxville

A specific instance of the procedure used in installing mains beyond the city limits is the policy of the Knoxville Water Bureau. For many years past that body has made it a practice to own and supervise all water mains located within the boundaries of public streets and roads, both inside and outside the city limits. This policy has been considered particularly wise, because it made possible the full control of the water distribution system at all times. Details of the policy for extending mains include:

"1. Persons desiring the extension of water services to new subdivisions shall pay all costs thereof. The size, type and installation of the required water lines must meet the approval of the Board, and it is desirable that the lines be constructed by its forces or directly under its supervision.

"2. Upon completion of the lines and their approval by the Board, full title and control thereto shall be conveyed to the Board. In consideration therefor, the Board will agree to operate and maintain the lines, and to furnish water service therefrom in accordance with the regular rules, regulations and rate schedules for such service as they may now exist or as they may be changed or modified hereafter.

"As further consideration, the Board will repay to the party, or parties, advancing the cost of constructing the lines, for a period of five years (but no longer) from the date of completion of the lines and their acceptance by the Board, the following sums, the total payments not to exceed the original cost of the mains to which consumers are attached:

"For each consumer attached to the lines within the above five-year period, and who signs a contract for water service for a minimum period of three years, as follows:

For each consumer attached to 2-in. lines, the sum of	$25.00
" " " " " 3-in. " , " " "	30.00
" " " " " 4-in. steel or transite lines	35.00
" " " " " 4-in. cast-iron lines	45.00
" " " " " 6-in. steel or transite lines	50.00
" " " " " 6-in. cast-iron lines	60.00"

As will be noted, this policy is sufficiently elastic to enable the department to handle most any reasonable proposition without having to present the problem to the governing Electric Power and Water Board for clarification. The policy as laid down is a broad general policy, and if its intents and purposes are complied with, minor deviations that are applicable to the particular problem in hand are not questioned by the governing body.

Cost Accounting for Water Utilities

By R. M. Sedgwick

TO ANYONE who is not an accountant, cost accounting usually means an involved accounting procedure by which the cost of a piece of machinery, such as an automobile, is calculated. It is true that such a determination of manufacturing costs is a complicated matter, but it should be pointed out that the "cost accounting," if such it may be called, applicable to water utilities is a very simple matter. For the most part, water works cost reports call for little more in the way of basic information than a running record of units of work performed within a given time, and some assembly of costs shown by records covering expenditures. After these have been obtained, unit costs are merely simple division.

Any series of cost reports, even though it may be simple, does provide data for the control, by management, of business operations. An intelligent interpretation of cost reports which are adequate and timely will disclose the efficiency with which resources are employed, and will fix the responsibility for inefficiencies. That such cost reports are not more extensively used in the water utility field is probably due to two reasons: (1) the lack of uniformity in general accounting, which precludes comparisons between utilities; and (2) some lack of understanding regarding the conclusions which may be drawn from cost reports as well as of the simplicity of the reports and the ease with which the basic data from which they are prepared may be obtained.

Privately owned water utilities in California, all of which are subject to regulation by the State Railroad Commission must follow a code of accounts promulgated by the commission. Although several attempts have been made to bring municipally owned water and other utilities under the jurisdiction of this commission, all such efforts to date have been unsuccessful. In most cases, publicly owned utilities do endeavor to keep their accounts and set forth the results of their operations in a manner

A paper presented on October 23, 1941, at the California Section Meeting, Fresno, Calif., by R. M. Sedgwick, Acct., East Bay Municipal Utility Dist., Oakland, Calif.

which, for all practical purposes, coincides with the code for privately owned utilities. Thus, while it can be assumed that the accounts of all water utilities, privately or municipally owned, follow the same general pattern, the only practical result is some uniformity in the general headings of the statements prepared from the accounts.

Lack of Uniformity in General Accounts

Actually, except by chance, there is no uniformity between any two utilities in the character of the charges that are made to particular accounts. For example, it would seem a simple matter to make a comparison between two or more water utilities by determining the cost experienced by each for commercial expense per meter per year. Any analysis of such expenses, however, will promptly disclose that the same items do not always go to make up the total commercial expense shown by the different enterprises. In one utility, no part of the expense for occupancy of a business office located in owned quarters in the same building with the general offices, or in the city hall, may find its way into commercial expense, while commercial expense for a second utility may include the rental and other operating expenses if the business office quarters are leased. Similarly, a third utility may make some charge to commercial expense resulting from a prorate, upon the basis of square footage occupied by the departments which are housed in one building.

This lack of uniformity in the general accounts, of which the above is but one of many illustrations, precludes comparisons, so that, for the water utilities, there are no unit costs of any definite value by which one utility can, through comparison with another, conclude that its own results are good, bad, or indifferent. Even though there are no usual "standards of the industry" with which a given water utility may make comparisons, cost reports reflecting only conditions within the utility itself are of very definite value to its management.

Value of Efficiency Reports

While cost reports usually present the cost in dollars and cents of units of work performed, there are some activities the efficiency of which may be better judged from reports which do not necessarily disclose costs. For example, if reports show the man-hours of labor expended in installing a service to the meter serving a customer, a comparison of efficiency can be made over a period of years without consideration of the different wage scales which may have been in effect from time to time. Such comparisons might, over a period of a few years, conceivably show a greater efficiency as indicated by decrease in man-hours employed at the same time as dollar and cents costs have increased decidedly.

Upon the same basis, a report for each collector, showing the number of bills taken out for collection, number and percentage of bills collected, and amount collected, is definitely of more value than a report showing a cost in cents per bill collected. By establishing a standard of performance in units of work performed, and by measuring performances against that standard, it is thus possible to draw proper conclusions from such statistical reports as to efficiency of individual employees from day to day, without the preparation of reports that include costs.

As has been stated previously, the major purpose of cost accounting is to insure that the resources available for a particular job have been efficiently employed. This information may sometimes be developed as a by-product of the determination of costs. For example, in the East Bay Municipal Utility District, in accounting for the time of construction equipment chargeable to particular jobs, the daily report of use for each piece of equipment is designed to furnish complete information for the eight hours of each working day. For idle time the daily reports show whether the equipment was not assigned, was moving, was in the shop for repairs, was broken down, or was idle because of lack of work for it on the job. From monthly tabulations of these reports, equipment which has been hoarded by particular foremen is "smoked out" and put to use. Some investment in additional units has thereby been avoided, and the equipment is employed to its fullest advantage.

Intra-Utility Cost Reports

Cost reports may also be prepared covering certain activities within the water utility that are worthy of some study, since they show the trend of costs; but a comparison of cost per unit of work performed is of indefinite value. A cost report showing cost per million gallons pumped, or cost per million foot-gallons lifted, for a number of pumping plants in the same system, is of no value for comparison of unit costs between different plants, since no two plants are identical in design, discharge pressure, and other operating conditions. Cost reports of this character are not valueless, however, since such unit costs assembled for each separate plant over a period of time may disclose information as to loss of efficiency.

If a water utility conducts a shop for the repair of its own water meters, an adequate cost report, to be of maximum value, should show labor, material, and total costs in terms of cost per meter repaired. If the cost of repair material increases disproportionately, it may indicate a tendency to replace parts when replacement may not always be necessary. Although meters of various sizes will be handled by such a shop, the labor costs can readily be allocated, on an arbitrary basis if necessary, between the various sizes of meters.

Control of Automotive Equipment

Every individual, regardless of his occupation or position in the business or professional world, seems to consider himself an expert in his knowledge of the comparative merits of all makes of motor cars. If those concerned with operation of the automobiles of a water utility can lay aside their prejudices and consider the facts as developed by cost figures, such study will be found to be well worthwhile. It is the practice in some large utilities to charge all operating expenses for automotive units of the same make and type to one account without breakdown of the cost of operating individual units. While this breakdown is more expensive in clerical labor, the data obtained are of sufficient value to warrant the expense. Units of the same make and model will show widely varying unit costs not always in accordance with the varying conditions under which they may be operated. In many cases, inherent weaknesses in the machines themselves will be disclosed, and remedies can be profitably applied.

In addition to cost figures in dollars and cents for operation of automotive units, to give adequate information from which to draw proper conclusions, the report should include consumption of gasoline in miles per gallon, and indicate the rate of consumption of oil. For use when considering reasonableness of the cost of repairs, proposed or completed, the cost report should also give information as to age of each unit (preferably in months), the total mileage which the unit has traveled, and cumulative costs during the entire period of ownership. If there is a sufficient amount of hauling by heavy units, improper conclusions may be drawn from cost figures based only upon miles of travel, and the unit costs should be shown in terms of ton miles.

The East Bay Municipal Utility District has obtained considerable increase in miles of transportation delivered per gallon of gasoline by concentrating upon those units shown by monthly reports to be below par in this respect. This was done not only through adjustments or repairs disclosed to be necessary by test runs of individual cars, but also by investigating the driving habits of the individuals to whom the cars were assigned. In addition, something has been accomplished merely by furnishing drivers of the same kind of units in equivalent service with monthly information regarding miles per gallon of gasoline for their particular machine as compared with the average for the fleet of similar units.

As an outstanding example of what can be accomplished by detailed study of the cost of operation of motor vehicles, it was reported by the Department of Water and Power of Los Angeles for the year ended June 30, 1940, that studies made from its cost statistics had shown it to be most

economical to effect a trade-in of light passenger cars during the first two and one-half to three years of their lives, thereby avoiding major overhauls and securing a higher trade-in allowance. The department reports that after adopting this policy (established from a study of its cost statistics), an actual saving in cost in excess of one cent per mile was obtained, with the additional advantage to the department of having at all times a better looking and more up-to-date passenger car fleet.

It is not the purpose of this paper to define what constitutes a complete series of cost reports, but rather to call attention to the importance of cost reports and to point out some of the results which may be obtained through intelligent consideration of such reports by management. The activities to be covered by cost reports which will be of value to a given water utility should be decided by the management; and such reports will vary with the size of the utility, the number of its employees, and the conditions under which it operates.

Comparison of Estimated and Actual Consumption From the Birmingham Industrial Water Supply System

By A. Clinton Decker

A REPORT made to the Birmingham (Ala.) Industrial Board in 1931 emphasized the need for the development of an additional supply of water for industrial purposes if expansion of existing industries and establishment of new industries was to be possible in the Birmingham district.* This district is abundantly blessed with large quantities of raw materials, especially those required for production of iron and steel. The major deficiency was water. With possibly one exception, the city is the only one of its size industrially in the country which is not located on a river, lake or body of water from which a supply for industrial purposes is available.

In July 1932, the City Commission of the City of Birmingham appointed an engineering commission to study further the industrial water supply problem and to make recommendation regarding the need as well as the engineering and economic soundness of such a project.

The Engineering Commission completed its report early in 1933 and on December 15 of that year the City Commission filed an application with the Public Works Administration for funds with which to construct the project. In this application was included the engineers' estimate of consumption of water from the proposed new system. The Engineering Commission had estimated that consumption would average 10 mgd. during the first year following completion of the project and that consumption would increase at the rate of 5 mgd. each subsequent year. Because of the character of the industries in the Birmingham district the annual consumption was based on a 365-day year. When the application was reviewed by the Engineering and the Finance Division of the P.W.A., exception was taken to the 365-day basis for estimating water consumption

A contribution by A. Clinton Decker, San. Engr., Tennessee Coal, Iron and Railroad Co., Birmingham, Ala.

*A description of construction work on this project, by the same author, was published in the January 1938 JOURNAL (vol. 30, p. 56).

and it was recommended that tables be prepared showing consumption on the basis of a 300-day year. During the eighteen months subsequent to filing the application additional industries had indicated their probable use of water, prompting the P.W.A. to ask the Engineering Commission to submit a new estimate of consumption for the first year, at 13 mgd. for 300 days, and for subsequent 300-day years. The engineers complied with this request, but, in addition, submitted a table of estimated consumption "based on all customers using water for 300 days a year and 70 per cent of the customers using water an additional 65 days per year. Even this consumption is very conservative when it is noted that of the actual consumers who are assured as customers immediately upon completion of this plant, those who are 365-day customers represent 83.5 per cent of the water used."

The estimates in the original application, December 15, 1933, indicated that sales of water during the first, second and third years after completion of the project would be 3,650, 5,475, and 7,300 mil.gal., respectively. Actual sales of water during these years were 3,289, 5,729, and 6,882 mil.gal. The ratios of actual sales to estimated sales were 90.1, 104.6 and 94.2 per cent respectively for each of the first three years. The total estimated sales for the three years was 16,425 mil.gal.; the actual sales, 15,900 mil.gal., or 96.8 per cent of the amount estimated on December 15, 1933.

The revised estimate referred to above was included in a revised application dated July 9, 1935, which gave consumption figures as follows: first year, 4,492 mil.gal.; second year, 5,182 mil.gal.; and third year, 6,910 mil.gal.—a total of 16,584 mil.gal. for the first three years. The actual consumption as compared to these estimated quantities was 73.2 per cent for the first year, 114.4 per cent, the second, 99.6 per cent the third, and 95.9 per cent for the three years.

It is interesting to note that the estimates of the original application were accurate within 3.2 per cent over the three-year period and that the greatest variation of the actual from the estimated consumption in any single year was 9.9 per cent. The revised estimates of July 9, 1935, although anticipating increases in consumption less rapidly from the first to the second year than did the original application, were obviously too optimistic for the loading period of the first year. Some of the deficiencies in actual consumption during the first year as compared to the estimates are attributable to the fact that the impounding reservoir was not filled to a sufficient extent to permit the sale of substantial quantities of water until the spring of 1939. Water service was commenced on June 12, 1938, although the dam was not completed until October 1, 1938, the closure of the temporary spillway having been made during September. Preliminary operation of the system, which permitted sale of water prior to the completion of the project, was made possible by the construction of a temporary

spillway and the installation of temporary pumping equipment. The temporary spillway permitted the accumulation of approximately 1,000 mil.gal. in the impounding reservoir. The temporary pumping equipment was operated until the late winter of 1938–39, or until water in the impounding reservoir had reached an elevation high enough to permit delivery to consumers by gravity. The capacity of the completed impounding reservoir is 21,000 mil.gal. The designed capacity of the entire system is based on delivery of water at the rate of 60 mgd.

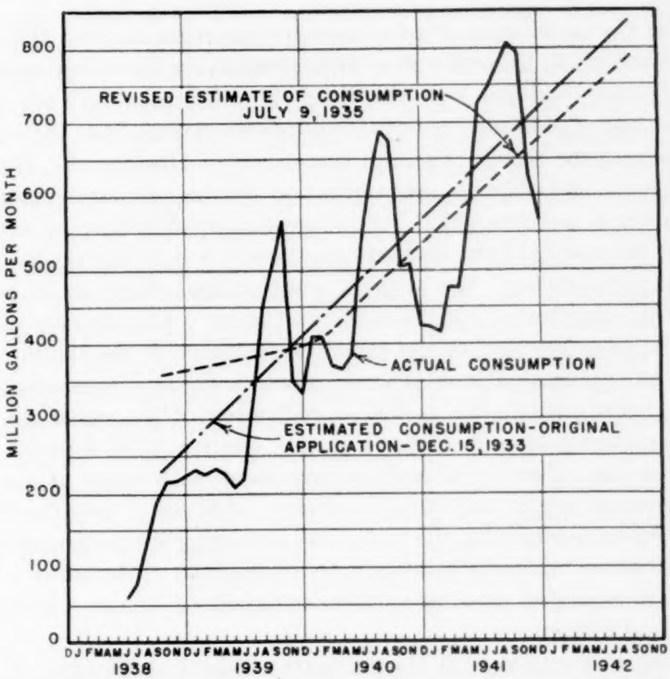


FIG. 1. Comparison of Actual and Estimated Consumption—Birmingham Industrial Water Supply System

Figure 1 shows the actual consumption by months and the estimated consumption on the basis of the two estimates. The curves for estimated consumption are, of course, based on uniform increases over the periods involved and as the original estimates did not attempt to indicate the probable seasonable variations, such variations have not been incorporated in the estimated consumption curves.

EDITOR'S NOTE: It may interest the reader to know that the industrial water system described in this paper was recently refinanced by a $4,250,000 issue of bonds which will yield the investor a return of 2.7 per cent.

Bacterial Densities From Fermentation Tube Tests

By Harold A. Thomas Jr.

WITH the postulation of a few assumptions regarding the distribution of bacteria in natural waters and by applying the calculus of probabilities, Greenwood and Yule (1), Reed (2) and others have developed a useful method of obtaining quantitative interpretations from the results of fermentation tube tests. Through the efforts of Hoskins (3), Halvorsen and Ziegler (4) and others in the publication of tables giving the most probable number of bacteria (M.P.N.) for various combinations of tubes and dilutions, the results of the mathematical analysis may be applied directly to many tests without the tedious computation otherwise entailed in solving the complicated equations of the theory. The obvious utility of this method has resulted in the general acceptance of the tables. There exists, however, an additional scheme by which the laborious computation may be circumvented; this is the simplification of the equations of the underlying theory so as to evolve a simple, easily applied formula for the M.P.N., giving values in substantial agreement with those in the tables. Such a formula would constitute a valuable addition to quantitative bacteriology by supplementing the tables and extending the statistical analysis to cases in which tables are lacking or are inadequate. Moreover, it should be of use in enlarging existing compilations so as to include a wider range of tubes and dilutions.

To those acquainted with the intricate theoretical background of the problem, the mathematical difficulties in the way of accomplishing any simplification may at first thought appear so formidable as to preclude the possibility of obtaining any useful result. Such, however, is not the case. A number of modifications in the theory that greatly simplify the calculation of a M.P.N. are possible. A simple formula thus obtained is $\lambda = \frac{P}{\sqrt{NT}}$, where λ is the most probable number, in bacteria per ml.; P, the number

A contribution by Harold A. Thomas Jr., Instructor in San. Eng., Harvard Graduate School of Eng., Cambridge, Mass.

of positive tubes; T, total quantity of sample in all tubes, in ml.; and N, total quantity of sample in negative tubes, in ml.

Since the equation was obtained by modifying some of the assumptions and steps of the usual theory, it does not give values of λ that agree exactly with those obtained by the original theory. Ordinarily, however, the deviations are so slight as to be of no practical consequence.

As an example of the use of the equation, showing the general order of agreement with values given in tables, it may be shown that an analysis gives results as follows: 10-ml. tubes—1+, 0−; 1-ml. tubes—1+, 4−; and 0.1 ml. tubes: 0+, 1−. Applying the equation, then, M.P.N. = $\frac{2}{\sqrt{(4.1) \times (15.1)}}$ = 0.25 bacteria per ml. as compared with the value 0.26 bacteria per ml. determined by the use of *Standard Methods* (5) tables.

If the tubes in the lowest dilution (containing the greatest amount of sample) are all positive, the complete omission of this dilution from the computation will improve the agreement between the simple formulation and the values in the tables. This is due to the divergence in the two methods when N is less than 5 per cent of T. The discrepancy does not impair the usefulness of the simple formula, for in a well constituted test, N should be greater than 5 per cent of T in order to develop the full measure of precision obtainable in the final result. If N is less than 5 per cent of T the expedient of omitting the lowest dilution ordinarily brings the two formulations into substantial agreement. In tests with a preponderance of the sample in positive tubes, the lowest dilution may be omitted without perceptible influence upon the value of the M.P.N. This is well known to persons conversant with the underlying theory, and may readily be verified by a precursory examination of M.P.N. tables.

Application of the Formula

It is interesting to note that the equation is not limited to any numbers of tubes or series of dilutions, but may be used on all types of fermentation tube tests including those of irregular dilutions and numbers of tubes. Therefore, the formula may be applied in the absence of tables to form an estimate of bacterial density in tests, such as are sometimes necessitated in the course of research, wherein uniform numbers of tubes and regular series of dilutions are not feasible or even possible. This may be the case, for example, when the total amount of sample is limited, or in the case of breakage or doubtful tests, or for any other occasion when it becomes desirable or necessary to reject some of the original tubes inoculated.

Many comparisons covering a wide variety of tests have been made between the M.P.N. given by the equation and that given by tables. These

have revealed the average disparity between the two formulations to be about 7 per cent. Seldom does the difference exceed 15 per cent and not infrequently do the two methods coincide. This is indeed a remarkable degree of agreement in view of the simplicity of the equation contrasted to the complexity of equations of the usual theory. It is evident, then, that the simple formula for estimation of bacterial density should be satisfactory in many practical instances of routine analysis where no great precision of measurement is required. Moreover, in the event the test under consideration is one not included in published tables and it is desired to ascertain the M.P.N. in accordance with the theory as developed by Reed, the equation provides a valuable aid in the application of the method of successive trials of Hoskins (3), by supplying a first approximation reasonably close to the desired value. It should always be remembered, however, that all theory of probability is predicated upon certain arbitrary initial assumptions that may or may not apply in any particular case. The lack of exact knowledge of whether or not these assumptions obtain in the instance at hand will limit to some degree the confidence that may be accredited the final result. Indeed, a number of different sets of assumptions may be formulated regarding the randomness of bacterial distribution. Each of these, mathematically developed, leads to a rational method of estimating bacterial density. Thus a variety of M.P.N. values may be calculated, each varying slightly from the others, depending upon the initial assumptions made.

Actually, the above equation was originally derived from assumptions closely similar to, but not quite identical with, those of Greenwood and Yule and of Reed. In the vast majority of routine analyses, however, mathematical discriminations of this order are of no practical significance, since the difference in numerical result for the M.P.N. as computed from the several theories is so slight as to be obscured by uncertainties of interpretation inherent in the nature of the test itself. It would appear, then, that in the many cases where a high order of precision is unnecessary, the simplicity and ease of applying the various formulations should determine the most generally useful method. This would of course indicate the use of published tables insofar as possible, together with the supplemental use of a simple equation giving results in substantial agreement with the established theory.

Dispersion of Frequency Distribution

In addition to the computation of the M.P.N., which is the modal value of bacterial density in the frequency distribution developed in the probability theory, some investigators, including Haldane (6) and Halvorsen and Ziegler (4) have delineated useful methods of measuring the

dispersion of the frequency distribution. While such measures are valuable in that they may be used to form an idea of the reliability and significance of the M.P.N., they are cumbersome to apply without recourse to tables or graphs. To provide a simple approximate measure of the dispersion of frequencies about the M.P.N., the following formula for estimating, in a comparative sense, the reliability of the M.P.N. values obtained from various similar fermentation tube tests, was developed: $E = \dfrac{\lambda}{\sqrt{P}}$, where E is the mean error of estimate, in bacteria per ml.—a measure of the dispersion of the frequency distribution.

Due to the complex nature of the distribution curves given by all theories, it is not feasible to attempt to attach any more quantitative significance to measures of dispersion, such as E, other than that formed upon a comparative basis. Another reason for not placing any great measure of reliability upon the absolute quantitative significance of indices of dispersion lies in the uncertainty of the applicability of any particular theory with concomitant specialized basic assumptions in the extreme ranges of the frequency distribution. While it is true that slightly different basic assumptions may give theories differing insignificantly as to M.P.N., the same does not apply to measures of dispersion, which differ widely, with but small variations in the underlying hypotheses. While this limits the value of measures of dispersion used in the absolute sense, it does not limit their use in a comparative sense. Thus, in deciding as to the reliability of two independent tests upon the same sample, the result given by the test of the smaller value of E would be more precise. It is useful to note from this formula that the error of estimate decreases inversely with the square root of the number of tubes tested; i.e. to halve the error of estimate it is necessary to quadruple the number of tubes.

Summary

A simple method of estimating the most probable number has been presented, and instances wherein the use of such seems practical have been discussed. This formula may be written:

$$\text{M.P.N.} = \frac{\text{No. of Positive Tubes}}{\sqrt{(\text{No. of ml. in negative tubes}) \times (\text{No. of ml. in all tubes})}}$$

Most probable numbers computed by this formula deviate from values given by the usual method by amounts which ordinarily are insignificant. The formula is not restricted as to number of tubes and dilutions used and may be applied to all types of tests.

A simple method of estimating the reliability of fermentation tube tests has been described showing the importance of increasing the number of tubes tested where precision is desired.

References

1. GREENWOOD, M. AND YULE, G. UDNEY. On the Statistical Interpretation of Some Bacteriological Methods Employed in Water Analysis. J. Hyg., **16:** 36 (1917).
2. REED, LOWELL J. Drinking Water Standards. Appendix III. B. Coli Densities as Determined From Various Types of Samples. Pub. Health Repts., **40:** 693 (1925).
3. HOSKINS, J. K. Most Probable Numbers for Evaluation of Coli Aerogenes Tests by Fermentation Tube Method. Pub. Health Repts., **49:** 393 (1934). (Reprint No. 1621)
4. HALVORSEN, H. O. AND ZIEGLER, N. R. *Quantitative Bacteriology.* Burgess Publishing Co., Minneapolis, Minn. (1938).
5. *Standard Methods of Water Analysis.* Am. Public Health Assn. and Am. Water Works Assn., New York (8th ed., 1936).
6. HALDANE, J. B. S. Sampling Errors in the Determination of Bacterial or Virus Density by the Dilution Method. J. Hyg. **39:** 289 (1939).

Evaluation of Coliform Organisms in Water

By F. R. Georgia

THE work of Hoskins (1) and his predecessors on the concentration of coliform organisms in water samples has been directed toward the determination of the most probable number (M.P.N.) of coliform organisms present in a sample when a certain number of fermentation tubes in a given series are positive. For any series of tubes a series of isolated M.P.N. values is obtained.

A better approach to the problem is to determine the range of concentrations of coliform organisms most likely to produce a given result. This can be done quite readily where each tube in a series of fermentation tubes is inoculated with the same volume of sample. For example, in any such series, the most probable range (M.P.R.) of concentrations of coliform organisms to give all negative tubes would be between zero and the M.P.N. for $\frac{1}{2}$ positive tube; the M.P.R. for one positive tube would be from the M.P.N. for $\frac{1}{2}$ positive tube to that for $1\frac{1}{2}$ positive tubes; etc. Such ranges are not, of course, limiting ones, but only most probable ranges; since, for example, it is to be expected that occasional positive tubes would result from coliform concentrations below the M.P.N. value for $\frac{1}{2}$ positive tube.

The M.P.N. values for half-tube intervals are as readily determined from the tables published by Hoskins (1) as are any other values. They have been used in preparing Table 1 which gives both M.P.N. and M.P.R. values for several series of tubes. The skew in the probability curve will not affect the M.P.R. values since the limits for the various ranges were taken as the calculated values for the half-tube intervals. The values have been restricted to two significant figures, with the exception of those for the one hundred 10-ml. tube series, where three figures were necessary to show proper differences between adjacent values.

The use of M.P.R. values would eliminate the misleading definite values of the M.P.N. system, and would give a better picture of the accuracy of the determination being reported. Just as in the M.P.N.

A contribution by Dr. F. R. Georgia, Cornell Univ. Filtration Plant, Ithaca, N.Y.

TABLE 1

Comparison of M.P.N. and M.P.R. Values per 100-ml. Concentrations for Several Series of Tubes

NO. TUBES POSITIVE	100, 10-ML.		10, 10-ML.		5, 10-ML.		20, 50-ML.		10, 50-ML.		5, 50-ML.		10, 100-ML.		5, 100-ML.	
	M.P.N.	M.P.R.	M.P.N.	M.P.R.	M.P.N.	M.P.R.	M.P.N.	M.P.R.	M.P.N.	M.P.R.	M.P.N.	M.P.R.	M.P.N.	M.P.R.	M.P.N.	M.P.R.
0	0.00	0.00–0.05	0.0	0.00– 0.51	0.0	0.0– 1.1	0.00	0.00–0.05	0.00	0.00–0.10	0.00	0.00–0.22	0.00	0.00–0.05	0.00	0.00–0.11
1	0.10	0.05–0.15	1.1	0.51– 1.6	2.2	1.1– 3.6	0.11	0.05–0.16	0.22	0.10–0.32	0.44	0.22–0.72	0.11	0.05–0.16	0.22	0.11–0.36
2	0.20	0.15–0.25	2.2	1.6 – 2.9	5.1	3.6– 6.9	0.22	0.16–0.28	0.44	0.32–0.58	1.0	0.72–1.4	0.22	0.16–0.29	0.51	0.36–0.69
3	0.30	0.25–0.36	3.6	2.9 – 4.3	9.2	6.9–12.	0.32	0.28–0.38	0.72	0.58–0.86	1.8	1.4 –2.4	0.36	0.29–0.43	0.92	0.69–1.2
4	0.41	0.36–0.46	5.1	4.3 – 6.0	16.	12. –23.	0.44	0.38–0.51	1.0	0.86–1.2	3.2	2.4 –4.6	0.51	0.43–0.60	1.6	1.2 –2.3
5	0.51	0.46–0.56	6.9	6.0 – 8.0		>23.	0.58	0.51–0.64	1.4	1.2 –1.6		>4.6	0.69	0.60–0.80		>2.3
6	0.62	0.56–0.67	9.2	8.0 –11.			0.72	0.64–0.78	1.8	1.6 –2.1			0.92	0.80–1.1		
7	0.73	0.67–0.78	12.	11. –14.			0.86	0.78–0.94	2.4	2.1 –2.8			1.2	1.1 –1.4		
8	0.83	0.78–0.89	16.	14. –19.			1.0	0.94–1.1	3.2	2.8 –3.8			1.6	1.4 –1.9		
9	0.94	0.89–1.00	23.	19. –30.			1.2	1.1 –1.3	4.6	3.8 –6.0			2.3	1.9 –3.0		
10	1.06	1.00–1.11		>30.			1.4	1.3 –1.5		>6.0				>3.0		
11	1.17	1.11–1.24					1.6	1.5 –1.7								
12	1.32	1.24–1.36					1.8	1.7 –2.0								
13	1.40	1.36–1.45					2.1	2.0 –2.2								
14	1.51	1.45–1.57					2.4	2.2 –2.6								
15	1.62	1.57–1.68					2.8	2.6 –3.0								
16	1.74	1.68–1.80					3.2	3.0 –3.5								
17	1.86	1.80–1.92					3.8	3.5 –4.2								
18	1.98	1.92–2.04					4.6	4.2 –5.2								
19	2.10	2.04–2.17					6.0	5.2 –7.4								
20	2.23	2.17–2.29						>7.4								
21	2.36	2.29–2.42														
22	2.48	2.42–2.55														
23	2.61	2.55–2.67														
24	2.74	2.67–2.81														
25	2.87	2.81–2.94														
47	6.41	6.26–6.45														

system the use of larger numbers of tubes in a series makes the interval between adjacent values smaller, so also in the M.P.R. system the range values are more restricted and approach the M.P.N. values from both sides.

Effect of Antibiosis

Both systems suffer from certain assumptions that, unfortunately, are not always true. One of these is that the presence and growth of other bacteria will not influence the results of the tests for coliform organisms. This assumption is hardly warranted in view of the known antagonistic actions of bacteria. Waksman (2) has recently reviewed this field.* The values obtained for the concentration of coliform organisms in water are certainly too low at times because of such antagonistic actions. The term "overgrowth" which is frequently used in this connection is not necessarily descriptive of the actual action. Antibiosis is perhaps a better one.

The proposed revision of the Federal drinking water standard with its provision for inoculating fermentation tubes with 100-ml. portions, rather than 10-ml. portions, makes some consideration of antibiosis desirable. One 100-ml. tube is not the equivalent of ten 10-ml. tubes. In the first case any coliform organisms must compete with all the other organisms present, while in the second case any coliform organisms in a tube will be in competition with only about 10 per cent of the entire number and should be better able to survive and grow. By the same reasoning ten 1-ml. portions should be preferable to one 10-ml. portion. The proper size and number of portions will of necessity be determined by the coliform concentration to be evaluated and the limitations of time, materials, and equipment.

Data recently published by Noble (3) make it possible to test some of the hypotheses. The work reported seems to have been very carefully planned and executed, and the results are probably as reliable as any that could be obtained except by extending the number of samples examined. Noble examined 22 samples of water and compared the results obtained from one hundred 10-ml. portions with those from twenty 50-ml. portions and ten 100-ml. portions of each sample. The results are summarized in a table in which the samples are arranged in the order of increasing coliform concentration as indicated by the results from the 10-ml. portions.

In Table 2 the data of Columns 1 through 4 are taken from Noble's tabulation with the same order of samples. Columns 5, 6, and 7 give the M.P.N. values corresponding to the results in Columns 2, 3, and 4, while, in a similar manner, in Columns 8, 9, and 10 the M.P.R. values are given. In Columns 11 through 15, use was made of the M.P.N. values for the

* Abstracted in this issue of the JOURNAL, p. 620.

one hundred 10-ml. tube series (Column 7) to compute the number of positive tubes that should result in various other tube series as indicated by the M.P.R. values of Table 1 for each series. In doing this the as-

TABLE 2

Bacterial Quality of 22 Samples Expressed in M.P.N. and M.P.R. Values

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
EXPERIMENT NO.	NO. TUBES POSITIVE*			M.P.N. PER 100 ML.			M.P.R. PER 100 ML.			NO. OF POSITIVE TUBES CALCULATED†				
	10, 100-ml.	20, 50-ml.	100, 10-ml.	10, 100-ml.	20, 50-ml.	100, 10-ml.	10, 100-ml.	20, 50-ml.	100, 10-ml.	0, 100-ml.	20, 50-ml.	10, 10-ml.	5, 10-ml.	5, 100-ml.
10	0	2	1	0.00	0.22	0.10	0.00–0.05	0.16–0.28	0.05–0.15	1(+)	1(−)	0	0	0
6	2	2	2	0.22	0.22	0.20	0.16–0.29	0.16–0.28	0.15–0.25	2(=)	2(=)	0	0	1
5	3	5	4	0.36	0.58	0.41	0.29–0.43	0.51–0.64	0.36–0.46	3(=)	4(−)	0	0	2
19	2	5	4	0.22	0.58	0.41	0.16–0.29	0.51–0.64	0.36–0.46	3(+)	4(−)	0	0	2
7	3	5	6	0.36	0.58	0.62	0.29–0.43	0.51–0.64	0.56–0.67	5(+)	5(=)	1	0	2
9	6	2	6	0.92	0.22	0.62	0.80–1.1	0.16–0.28	0.56–0.67	5(−)	5(+)	1	0	2
11	6	7	7	0.92	0.86	0.73	0.80–1.1	0.78–0.94	0.67–0.78	5(−)	6(−)	1	0	3
1	4	6	9	0.51	0.72	0.94	0.43–0.60	0.64–0.78	0.89–1.00	6(+)	8(+)	1	0	3
12	3	5	9	0.36	0.58	0.94	0.29–0.43	0.51–0.64	0.89–1.00	6(+)	8(+)	1	0	3
22	6	10	13	0.92	1.4	1.40	0.80–1.1	1.3 –1.5	1.36–1.45	7–8(+)	10(=)	1	1	4
3	5	16	13	0.69	3.2	1.40	0.60–0.80	3.0 –3.5	1.36–1.45	7–8(+)	10(−)	1	1	4
21	9	5	14	2.3	0.58	1.51	1.9 –3.0	0.51–0.64	1.45–1.57	8(−)	11(+)	1	1	4
8	7	9	15	1.2	1.2	1.62	1.1 –1.4	1.1 –1.3	1.57–1.68	8(+)	11(+)	1–2	1	4
4	8	10	16	1.6	1.4	1.74	1.4 –1.9	1.3 –1.5	1.68–1.80	8(=)	11(+)	2	1	4
18	4	7	17	0.51	0.86	1.86	0.43–0.60	0.78–0.94	1.80–1.92	8(+)	12(+)	2	1	4
13	10	13	18	—	2.0	1.98	>3.0	2.0 –2.2	1.92–2.04	9(−)	13(=)	2	1	4
15	2	3	19	0.22	0.32	2.10	0.29–0.43	0.28–0.38	2.04–2.17	9(+)	13(+)	2	1	4
16	0	6	22	0.00	0.72	2.48	0.00–0.05	0.64–0.78	2.42–2.55	9(+)	14(+)	2	1	5
14	9	15	24	2.3	2.8	2.74	1.9 –3.0	2.6 –3.0	2.67–2.81	9(=)	15(=)	2	1	5
2	8	13	25	1.6	2.0	2.87	1.4 –1.9	2.0 –2.2	2.81–2.94	9(+)	15(+)	3	1	5
17	9	15	25	2.3	2.8	2.87	1.9 –3.0	2.6 –3.0	2.81–2.94	9(=)	15(=)	3	1	5
20	10	17	47	—	3.8	6.41	>3.0	3.5 –4.2	6.26–6.45	10(=)	19(+)	5	2	5

* Data in first four columns from Noble (3).

† Using M.P.N. values of one hundred 10-ml. tube series (Column 7), the number of positive tubes that should be obtained in various other series was determined using M.P.R. values of Table 1 for each series. (−), (=), (+) indicate that calculated numbers in Columns 11 and 12 are, respectively, less than, equal to, or more than the numbers in Columns 2 and 3.

sumption is made that the values in Column 7 are more reliable than those in Columns 5 and 6.

The following material is offered in support of this assumption. Hoskins and Butterfield (4) developed the formula:

$$P = 100[1 - (e^{-N\lambda})^K - (1 - e^{-N\lambda})^K]$$

where: P = percentage of samples giving determinate results, i.e., some tubes positive and some negative; N = size, in ml., of portion; λ = M.P.N. per ml.; K = number of portions of size N in each test; and e = 2.7183 (base of Naperian logarithms). The lowest M.P.N. value obtainable in any of Noble's series is 0.001 per ml. If this is used to calculate values of P for one hundred 10-ml. tubes and for ten 100-ml. tubes P = 63.2 in both cases. For higher M.P.N. values the results favor the one hundred 10-ml. tube series. For example, with the M.P.N. value of 0.0105 per ml., used by Hoskins and Butterfield in their table, P = 99.997 for one hundred 10-ml. tubes as against 98.6 for ten 100-ml. tubes.

The argument that the most accurate result is obtained from a series in which about half the tubes are positive would apply, as far as mathematical probability determines results, if comparisons were being made between series containing equal numbers of tubes. In the work under consideration, however, the number of tubes in each series was adjusted so that the same total volume of water sample, i.e., one liter, was used to inoculate each set of tubes. Under these conditions the most accurate data will be obtained from the series having the largest number of tubes. It would seem self-evident that the greater the number of portions into which a water sample is divided for inoculation into fermentation tubes, the greater the chance of separating coliform organisms one from another, and the greater the chance that each positive tube represents only one coliform organism. This goal is much more closely approached in a series of one hundred 10-ml. tubes than in either twenty 50-ml. or ten 100-ml. tubes.

These arguments show that both series give determinate results in about the same percentage of cases, with a slight advantage for the one hundred 10-ml. tube series over the ten 100-ml. tube series, and that the degree of refinement with which the result is measured is much greater in the case of the one hundred 10-ml. tube series. This last is also indicated by the magnitude of the differences between adjacent M.P.N. values for the two series.

Application of the Federal Standard

On the basis of the interpretation placed on the present Federal standard by some workers, that an M.P.N. value of 1.1 separates good waters from bad ones, it will be found, from an examination of Columns 5, 6, and 7, that the first nine samples of water would be passed in all of the series. All the remainder would be condemned on the basis of the results of the 10-ml. series (Column 7). Four additional, or a total of 13 samples, would get by in the 50-ml. series (Column 6), and five additional, or a total of 14 samples, would pass as judged by the 100-ml. series (Column 5); and the additional samples passed in the 50-ml. and 100-ml. series

are not always the same ones. Is this an indication of antibiosis in the larger portions? One strongly suspects it, at least in Samples 15, 16 and 18. In this connection it is of interest to compare Column 2 with Column 11, and 3 with 12. The computed values in Column 11 are smaller than those of Column 2 in four cases, equal in six, and larger in the remaining twelve. In Column 12 there are five smaller values, six equal, and eleven larger than in Column 3. In the 100-ml. and 50-ml. series the computed values, based on the results of the 10-ml. series, gave 31 and 34 more positive tubes than actually obtained. Again, is this an indication of antibiosis in the larger portions?

In Columns 13, 14, and 15 of Table 2, the numbers of positive tubes most likely to have been obtained in three additional series of tubes have been computed. The five 10-ml. series of Column 14 is that in general use now, while that of Column 15, of five 100-ml. tubes, is the one proposed for the new standard. Column 13 for ten 10-ml. tubes represents a feasible alternate choice.

Again on the basis that the M.P.N. value of 1.1 is the limit, the M.P.R. values of Table 1 for the above series indicate that 1.1 is within the range for one positive tube in the ten 10-ml. series, three positive tubes in the five 100-ml. series, and is the dividing line between zero and one positive tube in the five 10-ml. series.

On this basis the probable results for the ten 10-ml. series would pass four of the water samples and condemn eighteen; the probable results for the five 10-ml. series would pass nine and condemn thirteen; and the probable results for the five 100-ml. series would pass six and condemn sixteen. These results do not consider any possible effects of antibiosis. It is of interest to note that the five 10-ml. series is in complete agreement with the one hundred 10-ml. series with respect to the samples of water passed or condemned, while both the ten 10-ml. and five 100-ml. series are more severe.

Too much stress should not be placed on the above interpolated results. They are presented in the hope of stimulating further work.

Perhaps the most general application of the Federal standard is to rating the efficiency of water purification plants. Plants that are properly designed and operated seem to have no difficulty in meeting present bacteriological standards and should find no difficulty in meeting any such standards as may be adopted. Purification plants that are getting consistently negative results, day after day, with five 10-ml. tubes probably would get similar results with five 100-ml. tubes, while those that now get poor results with the five 10-ml. tubes would continue to get them unless antibiosis came to their aid.

If there is a general conviction—and this is open to question—that a finer scale for the evaluation of concentrations of coliform organisms is

desirable, the best way to accomplish it is to increase the number of 10-ml. tubes used rather than to use larger portions, such as the five 100-ml. samples suggested.

A standard based on the inoculation of ten 10-ml. fermentation tubes per sample is suggested, with the following limits: Not more than 10 per cent of all tubes run on samples from the same source shall confirm, and not more than two confirmed tubes shall be allowed on any one of a series of such samples. In the case of untreated ground waters the standard should be more stringent and require all presumptive tubes to be negative. Such a standard would not involve a change in present equipment, which is a point worthy of consideration under present conditions.

Conclusions

1. Antibiotic effects must be considered in the determination of M.P.N. values, especially if larger volumes of water are to be used for inoculation of fermentation tubes.

2. A system of most probable range (M.P.R.) values is suggested as preferable to the present M.P.N. values for coliform organism concentrations where each of a series of fermentation tubes is inoculated with the same volume of sample. The M.P.R. system does not lend itself to computing average results and would thus prevent covering up a poor result in an average value.

3. A study of Noble's data supports the first conclusion.

4. Low concentrations of coliform organisms are better detected by an increase in the number of 10-ml. tubes used rather than by the introduction of 100-ml. tubes.

References

1. HOSKINS, J. K. Most Probable Numbers for Evaluation of Coli Aerogenes Tests by Fermentation Tube Method. Pub. Health Reports, Reprint No. 1621 (rev., 1940).
2. WAKSMAN, S. A. Antagonistic Relations of Micro-organisms. Bact. Reviews, **5**: 231 (1941). (Abstracted in this issue of the JOURNAL, p. 620.)
3. NOBLE, RALPH E. Should Larger Portions of Water Be Tested for Coliform Bacteria? Jour. A.W.W.A., **33**: 1242 (1941).
4. HOSKINS, J. K. AND BUTTERFIELD, C. T. Determining the Bacteriological Quality of Drinking Water. Jour. A.W.W.A., **27**: 1101 (1935).

Discussion by *Ralph E. Noble*.* Dr. Georgia's analysis of the writer's data is a good example of what was hoped would happen. His most probable range approach will, no doubt, facilitate the thinking of those for whom the most probable number concept is difficult. The emphasis on antibiosis is quite proper. This phenomenon deserves considerable

* Principal Bacteriologist, Chicago Health Dept., Chicago.

attention to determine the extent to which it masks coliform indices at critical levels, according to the type of water treatment.

In the writer's opinion, one or both of two things should be done to determine the relative efficiency of 10-ml. and 100-ml. portions at coliform levels below 1.05 per 100-ml. First a sufficient number of experiments should be conducted with raw water in which coliform densities are controlled at levels ranging, in steps, from 0.5 to 2.0 or 3.0 per 100 ml., using five 10-ml., ten 10-ml. and five 100-ml. portions in parallel, following the standard procedure of identification of coliform organisms. Then the series should be repeated with sterile buffered dilution water (Butterfield's formula "C"). It would be easy and especially advantageous to run the two sets in parallel because of the advantage of using a common inoculum in those cases where the raw water appeared not to contain coliform organisms in 100 ml., thus necessitating the use of a titered pure culture suspension in sterile formula "C" water, after the coliform population therein had been stabilized for two or three days at refrigerator temperature. Such results would obviate interpolation from data derived from a different series and give an excellent check on the factor of antibiosis.

Concentrating Filter for Large Water Samples

By Bruce R. Ford and Millard F. Gunderson

THE apparatus described in the following pages is for use in the supplemental bacteriological examination of water supplies. The device permits the handling of large sample volumes, is simple in construction and easy to operate. It consists of a Berkefeld filter, encased in a metal cylinder, fitted to a water meter. To facilitate handling and provide mobility, the apparatus is fastened to a convenient mounting board. Figure 2 shows the original equipment ready for use attached to a high service pump. Figure 1 gives the construction details of the device after a minor improvement in the design.

The Berkefeld filter candle is 10 in. long, 2 in. in diameter and is of medium (*N*) porosity. The cylinder is made from standard 2-in. brass pipe. It is $10\frac{1}{2}$ in. long and is threaded with standard straight thread (16 threads per in.) for $\frac{3}{4}$ in. from the open end. The top of the cylinder is closed with a solid brass plate $\frac{1}{4}$ in. thick brazed on and machined smooth.

This top plate has a $\frac{1}{8}$-in. female tapped connection in the exact center. The connection is made up of a 2-in. nipple of $\frac{1}{8}$-in. brass pipe, a $\frac{1}{8}$-in. to $\frac{1}{4}$-in. standard pipe bushing, a $\frac{1}{4}$-in. standard pipe coupling, and the male half of an adapter from $\frac{1}{4}$-in. pipe threads to $\frac{1}{4}$-in. standard tubing threads. The female half of this tubing union remains on the copper tubing by means of which the device is attached to the water source, e.g., high service pump, laboratory tap, sill cock or fire plug.

The cap for the bottom of the cylinder is machined from a solid brass block. Its outside measurement is $1\frac{1}{8}$ in. in length and $2\frac{3}{4}$ in. in diameter. It is machined out inside to a depth of $\frac{7}{8}$ in. thus leaving a solid plate $\frac{1}{4}$ in. thick for the closed end. The threads extend into the cap $\frac{11}{16}$ in. and the diameter of the cap from thread to thread is $2\frac{5}{16}$ in. For the distance between the inside edge of the threads and the solid plate which forms the end of the cap, the diameter is increased to $2\frac{7}{16}$ in. to allow for a gasket

A contribution by Bruce R. Ford, Bacteriologist, Metropolitan Utilities District, Omaha, Neb., and Millard F. Gunderson, Assoc. Prof. of Pathology and Bacteriology, Univ. of Nebraska, College of Medicine, Omaha, Neb.

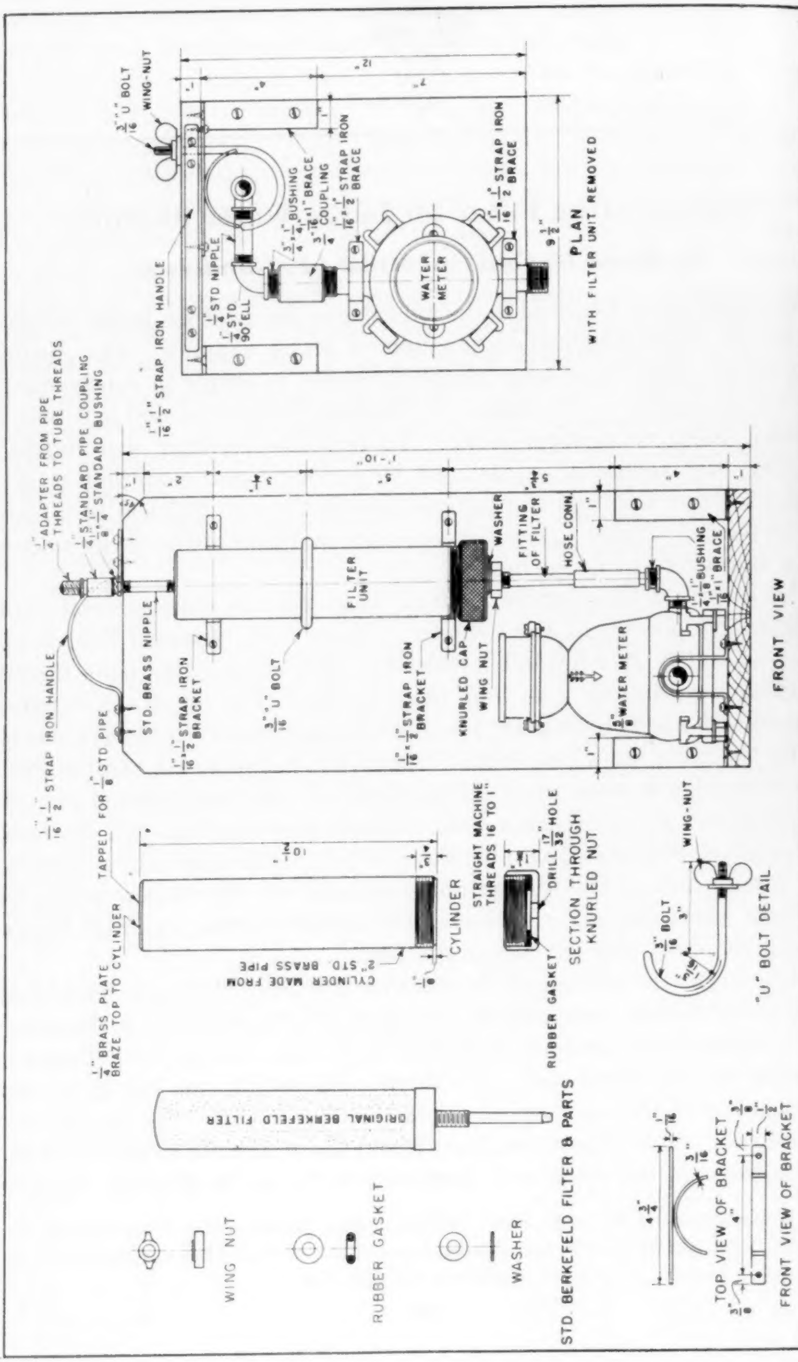


FIG. 1. Construction Details of Concentrating Filter

cut from $\frac{3}{16}$-in. rubber. The outside surface of the cap along the edge is knurled to provide a good handhold. A $\frac{17}{32}$-in. hole is drilled in the exact center of the end of the cap for the stem of the Berkefeld filter.

The water meter shown is an ordinary $\frac{5}{8}$-in. house service meter although a smaller one could be used. It is connected by means of the necessary pipe fittings and rubber tubing, as shown in Fig. 1, to the discharge stem of the Berkefeld filter.

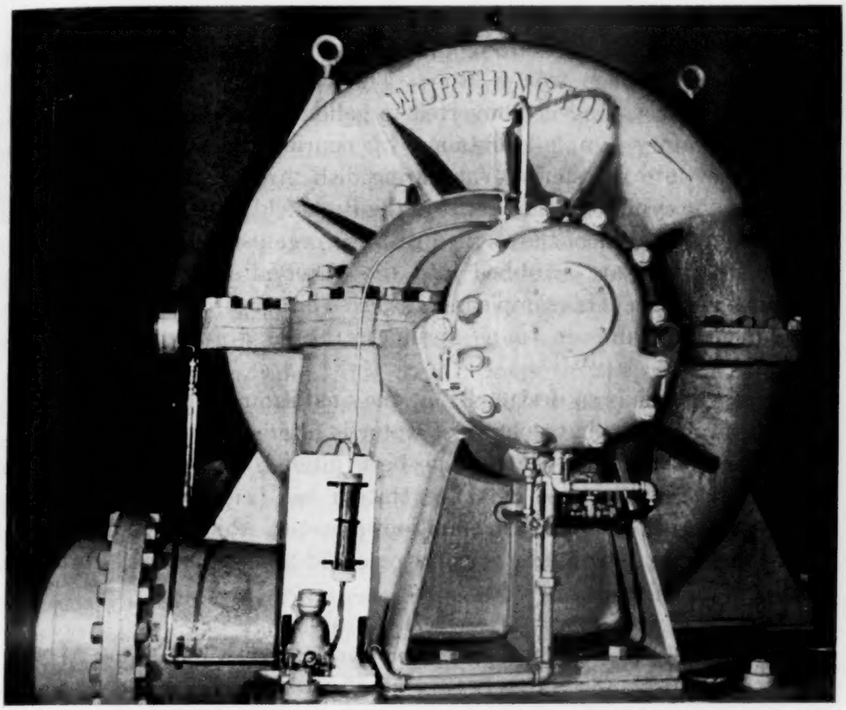


FIG. 2. Assembled Concentrating Filter Attached to a High Service Pump

Technic

Sterilization of the filter is accomplished in the autoclave. The cap for the bottom of the cylinder is placed on the stem of the Berkefeld filter with the rubber washer, the metal washer and the wing nut loosely in place. This assembly is wrapped in paper. The open ends of the cylinder and top connection are closed with paper. A 6-in. evaporating dish and a stiff bristled brush, e.g., a Fuller pastry brush, are wrapped separately. All these pieces are steam sterilized at 15 lb. pressure for not less than one hour. The filter and cylinder are assembled very carefully to avoid bac-

terial contamination and the cap tightened. The wing nut on the Berkefeld stem must be tightened only with the fingers, and not until after the cap is solidly in place. Otherwise, the Berkefeld candle might be broken by forcing it against one side of the cylinder.

The assembled filter is fastened to the mounting board against the semicircular brackets with the curved bolt and wing nut, and the rubber tubing from the meter is connected. The end of the copper tubing through which the apparatus is connected to the water supply is flamed, the union made, and the filter is ready for use.

The full operating pressure of the high service pump (110 psi.) can be used without damage to the filter. The volume of the water filtered, read in cubic feet, may be converted to gallons by use of the factor 7.48.

The laboratory sample is obtained by pouring the water remaining in the cylinder into the sterile evaporating dish through the connections at the top of the cylinder. The cap and the Berkefeld filter are then removed together. By means of the sterile brush the organisms present on the surface of the filter are scrubbed into the water already obtained in the evaporating dish. This sample is transferred either directly to the primary enrichment medium or to a sterile bottle for transportation to the laboratory.

This apparatus is so designed that the final sample volume is less than 100 ml. no matter what volume of water is filtered. On numerous occasions over 1,000 gal. of water have been filtered. It is obvious that in such cases a high degree of concentration has been obtained. Such a feature is desirable in the examination of water, which may or may not meet the Federal standard, for pathogens and non-pathogens of intestinal origin.

The authors wish to thank Walter S. Byrne, Gen. Mgr., James M. Keir, Supt. of Water Plants, Harry B. Stryker, Shop Supt., and James L. Jordan, Machinist, all of the Metropolitan Utilities Dist., for their valuable assistance in the construction of this apparatus.

Investigation of an Unusual Natural Water Softening

By D. W. Graham

An unusual case of natural softening of water, unparalleled in the records of the Los Angeles water system, occurred during June 1940, at Chatsworth Reservoir. At this time, the reservoir had a surface area of 350 acres, an average depth of 20 ft., a volume in storage of 2.25 billion gallons, and a total hardness of 120 ppm.

On June 5, a milky appearance was observed when routine samples were collected at the reservoir. This was assumed to be caused by supersaturation of dissolved oxygen, a not uncommon condition at Chatsworth Reservoir that spring. The condition was not recognized as abnormal until chemical analysis revealed that the hardness had suddenly dropped 30 ppm. (from 120 to 90 ppm.) due to a decrease in the calcium content. Significant chemical, bacterial and microscopical results during this period are shown in Fig. 1. The results for June 5 are of special interest. Increased biological activity was shown by the increase in *Anabaena* from 750 to 4,730 standard units per milliliter, an increase in dissolved oxygen from 8.3 to 13.0 ppm. and an increase in turbidity from 9 to 18 ppm., although the latter rise was due partly to the precipitation of calcium carbonate. The increase in pH from 8.6 to 8.9 and of carbonate alkalinity from 20 to 30 ppm. created favorable conditions for calcium carbonate precipitation. That actual precipitation must have occurred is shown by the decrease in total dissolved solids as reflected by the decrease in specific electrical conductance, the rise in turbidity, and the decrease in calcium from 30 to 21 ppm. The reservoir was treated with copper sulfate on June 10, and changes during the subsequent period of stabilization indicate what actually occurred.

The high bacterial counts were normal sequels to a decline in microscopic organisms; dissolved oxygen became subnormal due to aerobic bacterial action; and the removal of the normal calcium carbonate by precipitation reduced the pH and carbonate alkalinity. Inspection of these results

A contribution by D. W. Graham, Chief Chemist, San. Eng. Div., Bureau of Water Works & Supply, Los Angeles.

leaves little doubt that the softening was due to biological activity and that *Anabaena* was responsible. This ability of microscopic organisms to alter the chemical composition of a water through photosynthetic activity has been recognized and reported by various authorities (1, 2, 3, 4).

Experimental Investigation

To correlate field results, an attempt was made to soften water by biological action in the laboratory. In all, eight experiments were conducted, five of which proved unsuccessful due to inability to grow sufficient algae

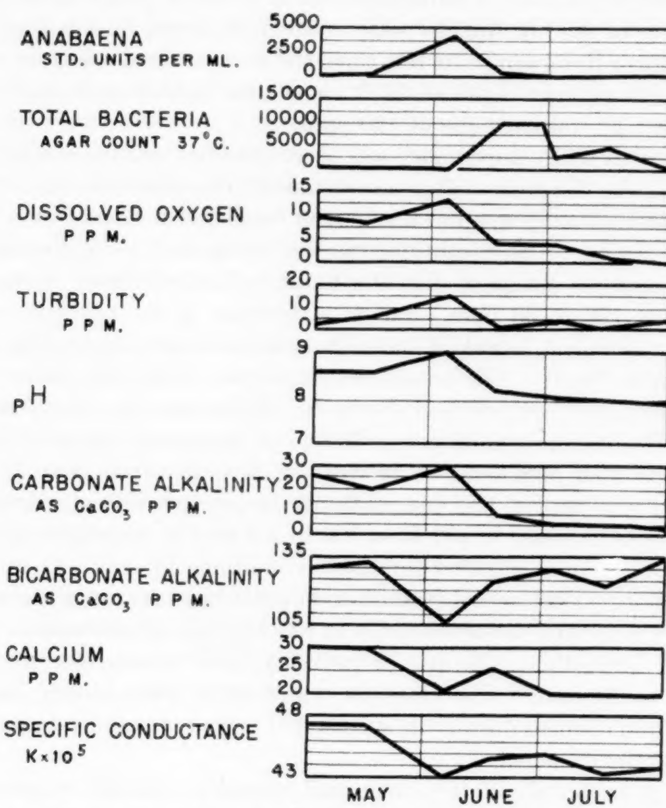


FIG. 1 Changes in Chatsworth Reservoir During Late Spring of 1940

to cause calcium carbonate precipitation. All experiments were conducted by putting two gallons of water in large cylindrical pyrex jars and allowing them to stand in a window where they received the afternoon sun. Encino Reservoir water was chosen for the first experiment as it most nearly approximated the original analysis of Chatsworth Reservoir water. The

first experiment was the most successful, and after three subsequent failures, Silver Lake water was used due to its higher bicarbonate content. Table 1 shows the characteristics of the water used for the three successful experiments. At varying intervals, depending on the appearance of the water, samples were withdrawn and analyzed for calcium, magnesium, and pH. When action had apparently passed its peak, as determined by general appearance and drop in pH, an approximation of the microscopic organisms present was made.

Inspection of Table 2, experiment Encino No. 1, shows active biological activity for more than fifteen days until the pH had risen high enough to reproduce the Chatsworth softening. It is noteworthy that the first sign of calcium carbonate precipitation occurred at pH 8.81, approximately the same as at Chatsworth Reservoir (8.90).

In the case of the experiments with the Silver Lake water, the softening started considerably lower (pH 8.50 and 8.45) and the biological action ceased before the pH was as high (pH 8.62 and 8.60) or the softening as far advanced as with the Encino or Chatsworth Reservoir waters. This discrepancy suggested investigation of the Langelier calcium carbonate saturation index (5) as a guide to indicate at what point precipitation might be expected. This index, therefore, was calculated for the time of highest pH prior to the start of calcium carbonate precipitation. For the Encino No. 1, Silver Lake No. 1 and Silver Lake No. 2 experiments, respectively, this index was +.88, +.87, and +.83. As the saturation index at Chatsworth Reservoir, during initial precipitation, was +.95, it seems that the optimum index for calcium carbonate precipitation for the local supply is between +.80 and +.95.

Seeking additional information, an investigation was also conducted on six samples which had been standing in the field in barrels and were used for determining the optimum dosages of copper sulfate for killing algae. Five of these samples showed calcium reduction. Three of the samples were pure cultures of *Cosmarium*, which, starting with a water of 75 ppm. calcium, reduced it to 62, 54, and 67 ppm., respectively, in two months' time. No record was kept of the intervening period. In the fourth sample, which started principally with *Closterium*, calcium was reduced from 32 to 24 ppm., but as *Synedra* and *Stephanodiscus* were also present in small amounts at the start and finish, no definite conclusion can be drawn regarding the responsible organism. The fifth sample, which started with *Synedra* and *Stephanodiscus*, was softened from 32 to 25 ppm. calcium and finished about 100 per cent *Aphanizomenon*.

In considering the specific organisms responsible for the bicarbonate utilization, it seems certain that *Anabaena* (Cyanophyceae) was the cause

TABLE 1

Characteristics of Samples Used in Laboratory Experiments

	Experiments		
	Encino No. 1	Silver Lake No. 1	Silver Lake No. 2
Chemical Characteristics	**Parts per Million**		
Specific electrical conductance ($K \times 10^5$)	42.3	69.9	73.8
Calcium	31	65	69
Magnesium	11	23	27
Total hardness as $CaCO_3$	123	259	285
Sodium	46	52	55
Potassium	5	5	6
Sulfate	40	160	165
Chloride	22	29	30
Silica	10	15	25
Iron	0.05	0.00	0.00
Fluoride	0.60	0.20	0.30
pH	7.9	8.0	8.2
Carbon dioxide	0.0	0.0	0.0
Carbonate alkalinity as $CaCO_3$	5.0	10	20
Bicarbonate alkalinity as $CaCO_3$	137	150	138
Total Kjeldahl nitrogen as N	0.320	0.520	0.360
Ammonia nitrogen as *N*	0.010	0.020	0.040
Nitrate nitrogen as *N*	0.06	2.0	4.0
Dissolved oxygen	2.6	9.3	7.9
Biochemical oxygen demand	2.3	3.7	3.8
Oxygen consumed	2.9	2.8	2.5
Color	12.0	10.0	3.0
Turbidity	5.0	3.0	3.0
Microscopic Organisms	**Standard Units per Milliliter**		
Diatomaceae			
Synedra pulchella	240	—	—
Amphiprora	16	—	—
Rhopalodia	4	—	—
Navicula	3	5	5
Melosira punctata	—	—	10
Cyanophyceae			
Sphaerozyga	8	—	—
Microcystis	24	—	—
Aphanizomenon	—	25	325
Chlorophyceae			
Ankistrodesmus	4	—	—
Pandorina	16	—	—
Scenedesmus	—	360	108

of the Chatsworth Reservoir phenomena; that *Synedra* (Diatomaceae) was primarily responsible for the Encino No. 1 experimental softening; and that *Scenedesmus* (Chlorophyceae) caused the Silver Lake No. 1 and Silver Lake No. 2 softenings. The increase in *Aphanizomenon* (Cyanophyceae) in the Silver Lake No. 1 experiment was not considered significant at the

TABLE 2

Results of Biological Softening Experiments

TIME OF TEST	EXPERIMENTS											
	Encino No. 1				Silver Lake No. 1				Silver Lake No. 2			
	Chemical Results in Parts per Million											
	Ca	Mg	T.H.*	pH	Ca	Mg	T.H.*	pH	Ca	Mg	T.H.*	pH
Start	31	11	123	7.90	65	24	261	8.01	72	24	269	7.91
3 days	—	—	—	—	—	—	—	—	—	—	—	—
6 days	31	11	123	8.23	—	—	—	8.03	72	24	269	8.38
9 days	31	11	123	8.50	—	—	—	—	64	24	259	8.45
12 days	—	—	—	—	53	24	231	8.50	60	24	249	8.61
15 days	31	11	123	8.75	—	—	—	—	—	—	—	—
18 days	20	11	94	8.81	39	23	192	8.62	56	24	239	8.60
21 days	—	—	—	—	—	—	—	—	56	24	239	8.45
24 days	17	11	87	8.85	40	23	195	8.43	—	—	—	—
27 days	—	—	—	—	—	—	—	—	—	—	—	—
30 days	17	11	87	8.70	—	—	—	—	—	—	—	—

TIME OF TEST	PRINCIPAL MICROSCOPIC ORGANISMS		
	Encino No. 1	Silver Lake No. 1	Silver Lake No. 2
Start	*Synedra* ...... 80% *Microcystis* ... 10%	*Scenedesmus* . 80% *Aphanizomenon* ..... 6% *Protozoa* 12%	*Scenedesmus* .. 20% *Aphanizomenon* ...... 60% *Protozoa* 20%
Finish	*Synedra* ...... 65% *Ankistrodesmus* 15% *Protozoa* 10%	*Scenedesmus* . 70% *Aphanizomenon* 20%	*Scenedesmus* .. 75% *Aphanizomenon* 15%

* T.H.—total hardness.

time but recent findings* prove that this organism also utilizes "half-bound" carbon dioxide. The field experiments show that *Cosmarium* (Chlorophyceae) acts in a similar manner.

* At Chatsworth Reservoir, from July 7 to 21, 1941, *Aphanizomenon,* the only organism present in significant quantities, increased from 935 to 4,200 standard units, the pH reached 9.3, and the saturation index + 0.97. The hardness dropped from 101 to 81 ppm.

Conclusions

The results of this investigation indicate that the Chatsworth Reservoir softening was caused by biological activity and that common water organisms of several different classifications have the ability to utilize carbon dioxide from bicarbonates. Under suitable environment, this photosynthetic activity will cause an increase in the Langelier index, carbonate alkalinity and pH; and a decrease in hardness, bicarbonate alkalinity, calcium and specific electrical conductance. The Langelier index has proved useful in the correlation of field and laboratory experiments in the past, and current work illustrates a further use of the principle. In the present investigation this index has been found more reliable in predicting the time of calcium carbonate precipitation than any other factor and for the local supply is approximately +.80 to +.95.

Organisms shown to utilize sufficient "half-bound" carbon dioxide in their metabolism to cause natural softening include *Anabaena* and *Aphanizomenon* (Cyanophyceae), *Synedra* (Diatomaceae), *Scenedesmus* and *Cosmarium* (Chlorophyceae), photomicrographs of which may be found in any standard reference book on the subject. It is probable that under proper environmental conditions many other algae will exhibit the same phenomena, so that further extension of this investigation is desirable.

References

1. Powell, S. T. The Effect of Algae on Bicarbonates in Shallow Reservoirs. Jour. A.W.W.A., **2:** 703 (1915).
2. Burnson, Blair. Seasonal Temperature Variation in Relation to Water Treatment. Jour. A.W.W.A., **30:** 793 (1938).
3. Smith, Gilbert M. *The Fresh Water Algae of the United States*. McGraw-Hill, New York (1933).
4. Whipple, George C., Fair, Gordon M., and Whipple, Melville C. *The Microscopy of Drinking Water*. John Wiley, New York (4th ed., 1927).
5. Langelier, W. F. The Analytical Control of Anti-Corrosion Water Treatment. Jour. A.W.W.A., **28:** 1500 (1936).

Laying Water Mains in Milwaukee

By Herbert Ihling

IN RECENT years the city of Milwaukee has embarked on a large scale program of street widening and resurfacing. As a result, the various utilities have been called upon to make all improvements to their underground systems necessary to meet the requirements of the new conditions. The Water Department, of course, has had its share of the work and problems involved in this program of improvement.

The short time allotted for the completion of such work, from the time the order to prepare plans is received to the time the water main must be laid, has been a major problem, allowing for no lost motion in the process. With the trend toward laying water mains in the populated or improved sections of the city, too, widely different problems from those encountered in the ordinary distribution system extension work in undeveloped areas have been encountered. In these developed business and industrial areas, water consumption is usually quite high, particularly in the present war production emergency, and water service must be maintained throughout the working week.

On all the new and wider arteries in the business, industrial and residential areas, the Water Department has adopted the dual system of water mains, locating the pipes as close to curb as possible, or, where feasible, in back of the curb, to eliminate the necessity of opening up the pavement in the future for new services, branch connections or repairs.

To maintain the water service during the working week, the old mains, generally located near the center of the street, are kept in service during the time when the new main is being laid. In laying these new mains, however, lead services are often cut, sometimes because of the difficulty in locating them or finding the curb stop boxes, and at others because the lead services do not run directly to the main or because two or more small leads are tapped to the main and then connected to feed one larger service. When a service is cut in this way, the contractor must repair it immediately

A paper presented on October 8, 1941, at the Wisconsin Section Meeting, Racine, Wis., by Herbert Ihling, Field Engr. of Constr., Milwaukee Water Dept., Milwaukee.

or supply water through hose connections to an adjacent building or hydrant. Similar difficulties are encountered with gas, electric and telephone services.

Main Installation Procedure

When a section of new water main has been laid between two valves, it is possible to make the wet connection to the existing cross-main in the intersecting street. In such a case the old cross-main may have to be cut off and capped so that the old main in the widened street can remain in service ahead of the new work.

The new main is then filled thoroughly and flushed and a water sample taken for laboratory analysis. If the sample is found satisfactory, the new main is tapped and all old services and branches are reconnected to it. Should the sample prove unsatisfactory, the main is reflushed until it is. Only very seldom are water samples from mains up to 16 in. in diameter found unsatisfactory after the mains have been flushed thoroughly. A chlorine residual of about 0.2 ppm., generally carried in the distribution system, has in most cases been sufficient to sterilize the new main. Because of the danger of pollution in wet trenches, however, chloride of lime to give a chlorine dosage of about 50 ppm. is placed in the pipe during the process of laying mains under such conditions.

After the new main is in service the old main can be abandoned. Very little old pipe is removed, this being done only where the new main falls in the same location as the old, usually at street intersections. Due to the difficulty in getting new gate valves this year, present gate valves are being removed from the old mains. Those which were installed recently are being overhauled and re-used, while the usable parts of the older ones are being salvaged and placed in stock for repair parts.

Installation Equipment

A crane with a clam-shell bucket seems to be the most suitable equipment for excavating trenches in widened streets because of the underground structures of the various utilities, as well as the water services and house drains which are encountered. Such a crane is used also to lower pipe and fittings into the trench. The trench machine is usually used in less congested areas and where there are fewer underground structures.

Air compressors and jack hammers are efficient in breaking out old pavements. In some instances where the street grade has been raised several times it has been necesssary to cut through two or three pavements. When pavements are to be laid soon after the water main is installed, either sand or gravel is used to backfill the trench.

Probably the most difficult problems occur at street intersections, for there are encountered all the various utility structures, such as electric, gas, telephone, and telegraph ducts as well as sewers and heating tunnels. In many instances these ducts are so close together that it is necessary to tunnel under them. In many cases it is also necessary to use such fittings as 45-degree bends or offsets to get around the ducts. The work at the intersections must be done in the shortest possible time to minimize interference with cross traffic as well as to prevent too long a shut-off when the wet connections are being made.

Since the mains in cross streets are usually very old, ranging in age from 30 to 69 yr., trouble is sometimes encountered because of inadequate shut-off at the gate valves. On several such instances a rubber gasket, known as the "Hyde-ro Rubber Ring"* was used to prevent the water from coming through the joint to be poured. In several instances, in connecting new and old pipe, however, there was a considerable difference in size of bell and spigot. The result was that the gasket would not fit tightly. A smaller sized piece of braided hemp was then driven into the V of the ring, expanding it and giving a watertight joint.

The rubber gasket was also very useful in repairing a leaky joint in a 6-in. branch to a hydrant. This branch was connected to a 16-in. main, which in turn was connected to a 20-in. main. There was only a 16-in. gate valve between the 20-in. main and the 6-in. branch and this valve could not be shut tightly. To get a watertight shut-off, it would have been necessary to take the 20-in. main out of service cutting off water service to several large buildings in the downtown area. Since the pipes were in place, the solid ring could not be used, so a diagonal cut was made in what was to be the top. The old jointing compound and hemp was then cut out of the leaky joint and the rubber ring, with hemp in back of it, driven home. This held back the water while the joint was poured. Leakage through the 16-in. gate valve was about 3 gpm. Since these solid rings come in sizes only up to 12 in., however, the clay dam method is still being used on the larger sizes of pipe.

On another occasion this past summer it was necessary to install a 20-in. sleeve on a line in which one of the 20-in. gate valves was not tight. Clay dams about 5 in. high were built in each pipe with a clay bridge to span the 5-in. gap between the two pipes which permitted the water to flow from one pipe to the other and then out through a blow-off. The sleeve was then moved into position and the joint poured. The pipe was filled with water and the joints inspected for leakage before backfilling. The clay was flushed out through the blow-off. The joints were found to be perfect. This 20-in. gate valve was leaking at the rate of about 8 gpm.

* Produced and distributed by Ralph H. Hyde, Campbell, Calif.

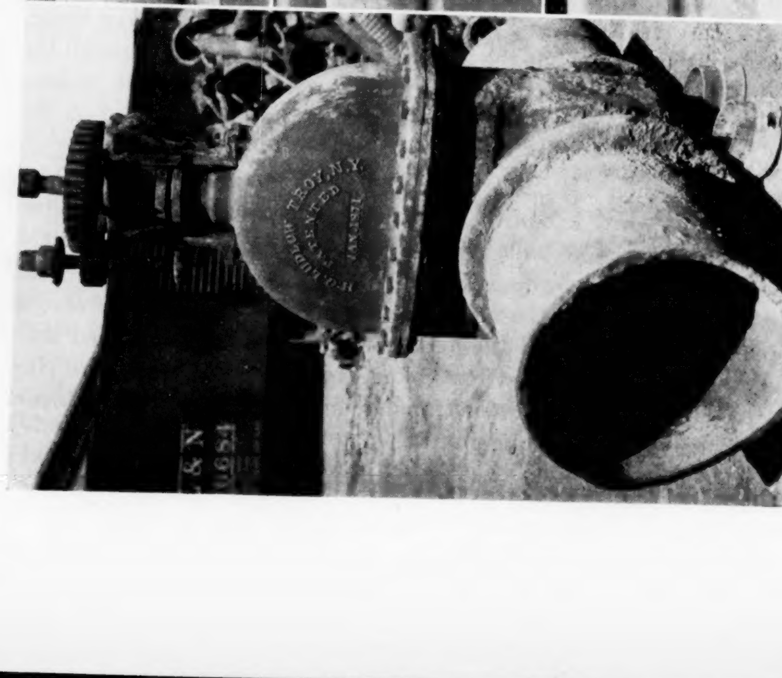


FIG. 1. 20-In. Gate Valve to Be Reinstalled; originally installed in 1872

FIG. 2. Variable Effects of Local Conditions Upon Cast-Iron Services; *Top and Center*—installed 1887; *Bottom*—installed 1928

Condition of Old Mains

It has been possible to obtain a great deal of information relative to the condition of some of the old water mains in the downtown section. These 6- and 8-in. mains were found to be especially clean inside, due to the high velocity of flow resulting from supplying the great demand for water through pipes of insufficient size. In streets upon which there were no trolley lines, there were few signs of electrolysis, but where trolley lines existed some sections of the old main at the intersections had to be removed because of excessive electrolysis. The walls of these pipes were so thin in places that one blow of a calking hammer could put a hole in them. In several instances more old pipe should have been removed and replaced but, due to a lack of funds and time, this was impossible. Additional gate valves, however, were installed in these old mains to reduce the length of shut-offs when future trouble might occur.

In cutting into a 20-in. water main which dead-ended at the Milwaukee River, 7 in. of silt were found in the bottom of the pipe. A 6-in. blow-off was placed at the end of this main and it was cleaned by means of flushing.

Backfill Material

In other instances, the old mains had been backfilled with material of a destructive nature, such as ashes, cinders, marsh muck and other acid or alkaline soils. Pipe in this type of fill showed signs of corrosion, and, when this corrosion was serious, the pipe was replaced. The various types of corrosion discovered were scaling, pitting and graphitization.

To protect the new pipe, either spent lime or limestone screenings were used with the sand or gravel backfill material. The spent lime, which is a by-product of the manufacture of acetylene gas, is placed in 2-in. layers at intervals of 24 in. vertically in the trench. This method is quite slow and difficult, so recently the pipe has been enveloped in limestone screenings, with a minimum of 6 in. of screenings over the top of the pipe.

The advantages of the limestone screenings over spent lime are that it forms a complete protective covering for the pipe, that it is slowly soluble in water, giving it longer lasting qualities, and that a great deal of time and labor is saved. Further study and experiments are being made to determine the advantages or disadvantages of limestone screenings as a regular cover for all future water pipes.

Since all pipe cutting of existing mains is done by the city distribution crew, there has always been a good check on the condition of the old pipe. The men's experience would tell them whether the pipe was "soft" or "hard," by the ease or difficulty with which they cut through the pipe. A great deal of information relative to the condition of the pipe in the distri-

bution system can be obtained from distribution crews when they cut the pipe for repairing leaks, and from tapping crews, when they make taps for new services.

Results Obtained

Considering the many miles of new pipe laid and the thousands of joints poured, the number of leaks which occurred were so few as to be practically negligible. Only four or five leaks were experienced this summer in 12 mi. of new mains and these occurred where wet connections were made and trouble resulted from leaky gate valves. During the last winter, however, there were about five or six leaks in new mains. These leaks may have been the result of improper heating of bells and spigots, and causing the joint compound to solidify before completely filling the joint. The fact that several of the leaks were at the side of the joint indicated this conclusion. Pipes were laid and joints poured when the temperatures were as low as 15°F.

Leaks in joints as well as cracked pipe and fittings can be caused by improper filling of the new main. Water should never be allowed to rush into the pipe at full pressure. Rather, the main should be completely filled very slowly and all vents kept open until all air in the pipe has been displaced. Air under pressure in a pipe will cut through joints, especially if they are of a sulfur compound, for this material is somewhat porous at the start.

Madison's New Watersphere

By L. A. Smith

THE Water Department of Madison, Wis., has recently put into operation a 100,000-gal. watersphere, 100 ft. high, to provide a more uniform pressure and a reserve for fire protection in its Nakoma area. This unique watersphere is a modern version of the elevated tank. It has a truncated cone base, 26 ft. in diameter at the bottom, tapering to 8 ft. at the top, and approximately 16 ft. high. This base cone supports a riser column 80 ft. high, with a base diameter of 8 ft. which tapers to a diameter of 6 ft. at the top. On this column rests the 30-ft. diameter watersphere. The steel plate employed varies in thickness from $\frac{1}{2}$ to $\frac{3}{4}$ in. with the exception of the upper half of the sphere, which is fabricated of $\frac{1}{4}$-in. steel plate. The watersphere was designed and fabricated by the Chicago Bridge & Iron Co.

The tank is designed to serve an area in the western portion of the city which is too high for satisfactory service from a 6-mil.gal. high service reservoir which floats on the distribution system. The cost of the entire improvement, including land, watersphere, and 1,000 ft. of 10-in. cast-iron main, connecting it to the distribution system, was approximately $20,000.

The city of Madison obtains its water supply from eleven deep wells, four of which are located in a group near a steam pumping station and the other seven at various points in the distribution system. These seven wells are known as unit wells and are self-contained pumping stations, including surface reservoirs and electrically driven pumps, pumping directly into the distribution system.

Madison is located on an isthmus between two lakes, the normal elevation of the water in the upper lake being approximately 845 U.S.G.S. datum. The eastern portion of the city, with the exception of a comparatively small area near the lake shore, is rather low, varying from an elevation of 860 to 900 ft. On the other hand, the western portion of the city, in which the University of Wisconsin is located, is rather hilly, being

A paper presented on October 8, 1941, at the Wisconsin Section Meeting, Racine, Wis., by L. A. Smith, Supt., Water Dept., Madison, Wis.

dotted with several terminal moraines laid down by retreating glaciers. Both Bascom Hall, the main hall at the university, and the Astronomical Observatory are located on such moraines.

Unsatisfactory Pressure Conditions

Until about fifteen years ago, the Water Department operated under a direct pressure system, i.e., water was pumped from the wells directly into the mains on which pressures fluctuated widely with water used. This arrangement was unsatisfactory for five reasons: (1) Pumping capacity had to be provided to meet maximum demands. (2) There were large fluctuations in pressure due to momentary peak loads. (3) Excessive water hammer conditions resulted from such closed system operation. (4) Electrically operated unit wells did not operate at the highest points of efficiency. (5) The load factor on the plant was very poor.

Fig. 1. Stage of Construction Progress July 10, 1941

To remedy these conditions, in 1926, a reinforced concrete reservoir of 6-mil.gal. capacity was built on a site of 1,056 ft. elevation, providing a maximum water level of 1,054.65 ft. This reservoir maintains adequate pressure to all parts of the city, with the exception of a comparatively small area with an elevation between 960 and 1,000 ft. Originally, there were only 20 or 30 houses in this area, and a small electrically operated booster pump was installed to provide adequate service pressures. At the present time there are in excess of 300 homes in this area, and in the interim additional booster pumps have had to be installed. At present two automatically operated booster pumps, one with a capacity of 325 gpm. and the other, 500 gpm., are in operation. The controls are so arranged that either one or both pumps can be put in service if necessary. This means that, previous to the installation of the watersphere, there existed in this area the same situation that formerly prevailed throughout the entire city; that is, there were large fluctuations in pressure and pressure was usually either too great or insufficient. Because of the satisfactory operation and adequate con-

sumer's service in the balance of the city, resulting from use of the 6-mil. gal. reservoir, it was deemed advisable to serve this area with an elevated tank. A site of 1,015 ft. elevation was therefore selected.

Solution of the Pressure Problem

A contract was let to erect, on this site, a 100,000-gal. elevated tank in which the entire 100,000 gal. would be stored at an elevation of 1,115 ft., that is, 100 ft. above ground level. This was planned to provide a minimum pressure of approximately 50 psi. in the entire area—sufficient for adequate domestic service. A 10-in. pipe line encircling the district was connected to the elevated tank by a new 10-in. line 1,000 ft. long.

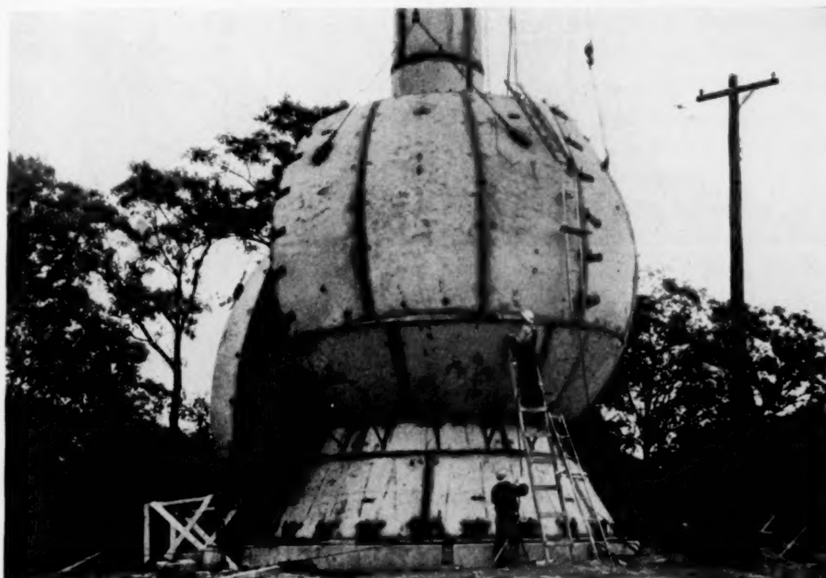


FIG. 2. Watersphere Assembly Progress—July 17, 1941

The tank offers three advantages over the previous method of operation: (1) It will assure maintenance of a uniform pressure. (2) It will provide a reserve for fire protection. (3) It will increase the efficiency of pumping, because the pumps will always operate at the highest point of the efficiency curve.

The people living at the higher elevations were in favor of elevated storage but wanted the tank at some other location than near their homes. This is a typical reaction under the circumstances. In such a case, the fair method of procedure is, of course, to select a location which will give the pressure required at the minimum cost. The site selected was at

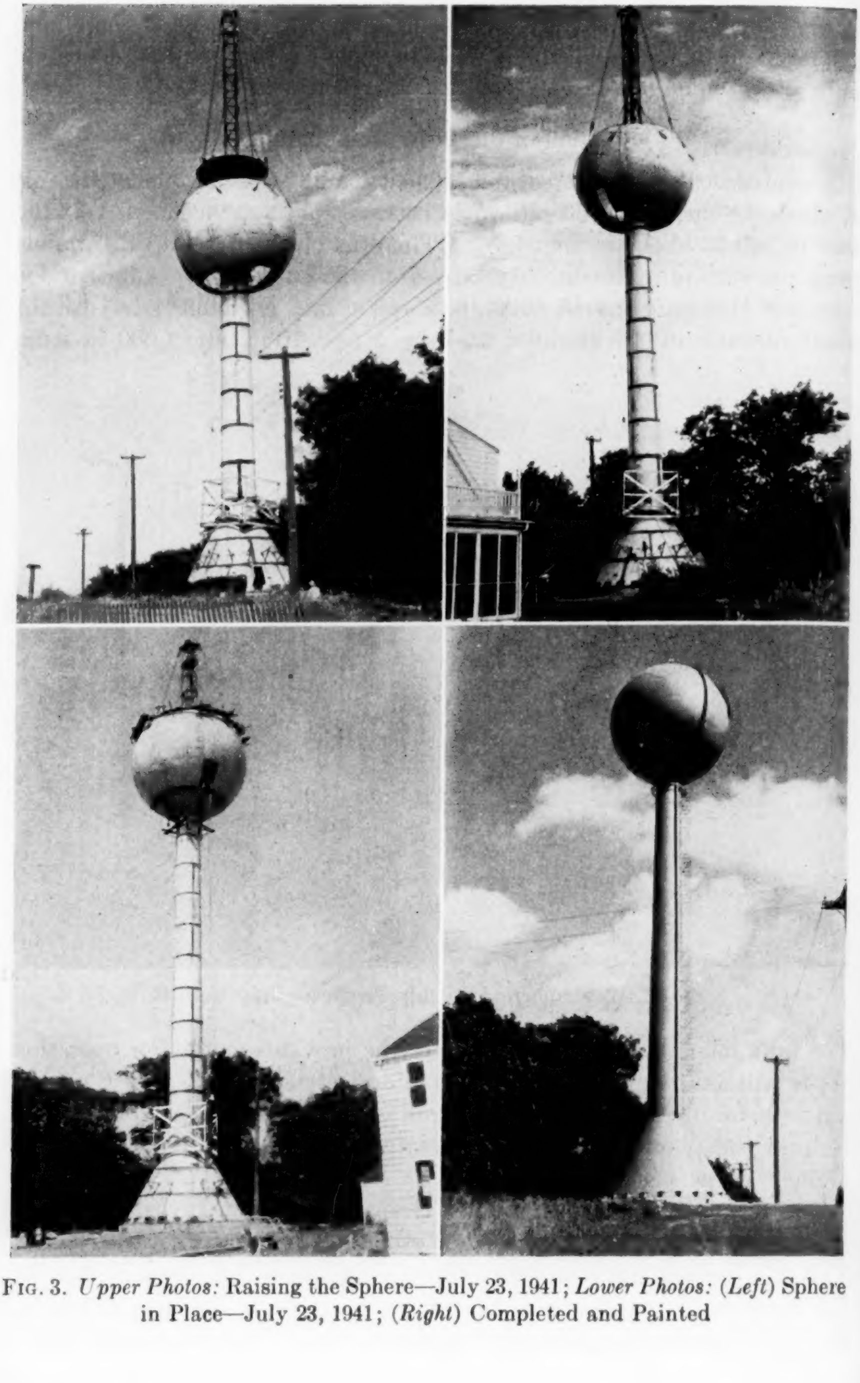


FIG. 3. *Upper Photos:* Raising the Sphere—July 23, 1941; *Lower Photos:* (*Left*) Sphere in Place—July 23, 1941; (*Right*) Completed and Painted

the opposite end of the district from the location of the booster pumps. The connecting link between the tank and the distribution system from this point was only 1,000 ft. long, so that the entire improvement, including the site, pipe line, watersphere, as well as engineering and contingent expenses, cost, as heretofore stated, only about $20,000.

Obviously, the higher the elevation which can be found, the lower the cost of the elevated tank; and the shorter the pipe line that must be installed, the lower the cost of the entire project. The problem, then, was rather simple, and the site selected was one which provided a reasonable elevation for the tank, as well as being fairly close to the 10-inch loop.

In advertising for bids for the elevated tank, the contractors were notified that it was to be located in a residential district and, in consequence, must be an ornamental type. The watersphere selected cost approximately 6 per cent more than the best designed conventional tank, but was selected for three reasons: (1) It is considered a unique departure in tank design, something new to the public eye, and more pleasing in appearance. (2) From a practical point of view, the cost of maintenance will be less, because less handwork in painting will be necessary. (3) There are no legs to support the tank, so that youngsters playing in the neighborhood cannot climb up the tank, with the chance of falling off.

The Board of Public Works and the Common Council were, at first sight of the picture of the tank, concerned with the stability of the structure. Therefore, a design was chosen which will safely withstand a wind velocity of 100 mph.

Giving considerable thought to the appearance, it was decided to paint the watersphere in a carefully chosen combination of a green-gray-blue color, designed to provide harmonizing tints to blend in with the background of trees and the sky. It was considered undesirable to paint the the name "City of Madison" on the side of the sphere, as it seemed that this would detract from its appearance, which is intended to be artistic in effect. The only lettering on the tank is on the top where an arrow pointed toward the airport is painted.

The tank is equipped with all modern devices, including automatic aeronautical lights, as requested by the Civil Aeronautics Authority; a cathodic rust prevention unit, to protect the inside of the tank from corrosion; and an automatic cone valve in the base of the tower, thus saving the cost of a special pit which would otherwise have to be built. It is provided with an automatic electrical control on the booster pumps, so that the range in ordinary operation is through a vertical height of about 8 ft. When the water recedes to 8 ft. below its maximum, the small booster pump starts automatically; and if it continues to recede, the larger unit also goes into service. Both stop automatically when maximum water level is reached.

ABSTRACTS OF WATER WORKS LITERATURE

Key. 31: 481 (Mar. '39) indicates volume 31, page 481, issue dated March 1939. If the publication is paged by issues, **31:** 3: 481, (Mar. '39) indicates volume 31, number 3, page 481. Initials following an abstract indicate reproduction, by permission, from periodicals as follows: *B. H.—Bulletin of Hygiene* (*British*); *C. A.—Chemical Abstracts; P. H. E. A.—Public Health Engineering Abstracts; W. P. R.—Water Pollution Research* (*British*); *I. M.—Institute of Metals* (*British*).

FIRE PROTECTION

Intermunicipal Co-operation in Fire Fighting. Emil F. Jarz. Pub. Mngmt. **24:** 46 (Feb. '42). *Excerpts.*

"Arrangements between two or more municipalities for the more effective use of available fire-fighting resources are desirable for at least two reasons: (1) to co-ordinate all equipment within certain 'target' areas to prevent possible conflagrations caused by bombing, sabotage, or other forms of attack; and (2) to avoid unnecessary expansion in personnel and equipment and thus avoid competition with the needs of the armed forces. Such arrangements are desirable in peace, as well as during war, and it is surprising that more than one-half of 30 of the largest cities in the country have not co-operated with nearby cities in working out detailed plans for 'outside' and mutual aid.

"There are three forms of co-operation: outside service, mutual aid, and joint departments. 'Outside fire service' refers to the dispatch of apparatus by a municipality to communities beyond its boundaries, whether or not these latter units possess their own protection facilities. Such aid is primarily one way rather than reciprocal and frequently there is no definite assurance of help to the outside agency. 'Mutual aid' applies to 'response on a well-laid-out plan on signal from fire headquarters, and with the very definite knowledge that the response will be made.' This second scheme is planned to work both ways, the communities in the compact agreeing to help each other in times of distress. Joint fire departments are those established by concurrent action or maintained and operated by the same personnel under one chief.

"Eighteen of the 20 states which contain the 30 municipalities surveyed have enacted a total of 41 laws authorizing intermunicipal co-operation in fire-fighting. Pennsylvania was first in 1917 with a law permitting second-class townships to receive aid from adjacent cities, townships, or boroughs. About ten statutes were enacted by these states during the Twenties, approximately 20 during the Thirties, and 8 in 1941. A 1941 California law states that 'worldwide conditions warrant emergency powers being extended to public agencies within this state in order that they may come to the assistance of one another, thereby supplementing their own means of local defense.'

"Most of the laws on intermunicipal co-operation in fire-fighting deal with the problem of 'outside fire service' by one governmental unit to others. Maryland and Rhode Island have not legislated in this field. Explicit mutual aid provisions are found in only five states (California, Missouri, New Jersey, Ohio and Pennsylvania). A 1938 New Jersey law on 'mutual emergency aid' provides for a joint meeting of the contracting

municipalities and authorizes them to acquire 'central offices, lands, buildings, and equipment' to accomplish the purposes of the act. Six states provide for the joint establishment, maintenance, or operation of fire departments (Indiana, Michigan, Minnesota, Missouri, Ohio and Wisconsin).

"The most liberal provisions are found in the recent California and New Jersey enactments which in effect authorize all governmental agencies within their boundaries to co-operate in fire protection.

"Most of the cities included in the study make no charge for outside fire protection service. Baltimore requires only that the municipality asking for help pay for any damages to equipment. The Buffalo fire chief may impose a charge or render service gratis, depending on the particular circumstances of each request for aid. The cities which make a charge, most frequently fix a certain amount per unit of equipment per hour. The rates range from $20 for the first hour and $15 thereafter in Chicago to $150 per unit of apparatus for the first hour and $100 thereafter in Milwaukee, which also requires a deposit of $300 from each governmental unit.

"Minneapolis, under a 1941 ordinance, charges $75 for the first hour for pumpers, 'quads,' and rescue squads; $65 for ladder trucks; and $100 an hour for water tower and certain other equipment. In addition, Minneapolis charges 90 cents an hour for each fireman, $1.00 an hour for each captain, and so on up to $1.95 for the chief engineer. There is also an annual fixed charge on the municipality receiving aid of $3 per $10,000 valuation of real and personal property, with a minimum payment of $100. A similar survey by Cincinnati resulted in a charge of one mill per dollar of assessed valuation of the municipality receiving 'outside service' and a charge to fire protection districts of two mills per dollar of assessed valuation. Cincinnati also charges a preliminary fee of $50 and a flat annual fee of $100 to each municipality that enters into a contract for aid.

"Portland, Ore., and Toledo, Ohio, charge $75 per hour for each piece of equipment and four cities (Detroit, Rochester, St. Louis and St. Paul) charge $50 an hour. Columbus, Ohio, charges $50 per hour plus $1.00 per mile traveled. Columbus also has agreed to provide complete fire service to Bexley for $17,000 a year, and Indianapolis guarantees Woodruff complete fire and police protection for $7,000 annually. Neither Bexley nor Woodruff has its own fire department.

"Ten cities provide that the fire chief may withhold aid for reasonable cause and that the city is not responsible for failure to respond. Minneapolis also reserves the right to withdraw equipment from an outside fire if needed within the city limits. Chicago will not send apparatus farther than 100 miles and Cincinnati sets an 'outer protection line.' Washington, D.C., has a similar rule. Nine cities require that response will be made only on receipt of alarm sent in by an officially designated individual.

"*Mutual Aid Plans.* Mutual aid is playing an important rôle in the 'Battle of Britain.' Our large metropolitan areas, however, have been slow to put such a plan into operation. Only five of the 30 cities included in this study are parties to mutual aid plans. The mutual aid arrangements of the Boston region and the Westchester County Plan, including certain parts of the New York metropolitan area, are outstanding.

"Boston and eleven other municipalities are joined in a mutual aid arrangement with fire alarm inter-connections. This plan, however, is but one of the mutual aid arrangements in the greater Boston area. These agreements are not based upon one single plan but consist of numerous separate understandings. In all, 27 cities have connected their fire alarm systems to those of adjoining communities so that each department knows when a neighbor requires help. Apparatus is automatically dispatched to adjacent municipalities in conformity with printed assignment cards. These cards 'provide for joint response to borderline boxes and to additional or simultaneous alarms. They also provide for automatic covering of unprotected areas. The plan has been so successful that it has grown to cover an area of 270 square miles and protects 1,750,000

persons.' Approximately 165 engine and hose companies and 81 ladder companies are co-ordinated for the protection of the region.

"Within the metropolitan area of New York City, there has been in operation since 1931 the 'Fire Chiefs' Emergency Plan' for suburban Westchester County. Forty-four of the 56 fire protection districts of the County are included within the plan. The mutual aid plan has worked out very well because all departments know what to do upon receiving a call from another district. Each fire chief has on his desk a printed card, 19 by 24 inches, showing the apparatus, manpower, and other information about the departments from which the chief may have occasion to summon aid. Legal difficulties were removed by a state law of 1931, authorizing local units to send fire companies to aid other towns and providing that any damage to or by apparatus shall be paid by the town requesting aid. A law passed in 1935 provides that the town which asks for aid shall pay specified sums for the injury or death of any fireman.

"*Court Decisions.* The prevailing rule is that municipalities cannot exercise their powers beyond corporate limits without legislative authorization. Local charters or ordinances cannot in themselves establish such a right.

"*Liability.* Indications are that a municipality with legal authority to send fire apparatus outside will be considered as operating in governmental capacity and therefore not liable for injury or damage. Conversely it has been held that a municipality rendering outside aid without authority of law was performing a proprietary function and liable for damages.

"Generally the courts will provide that firemen injured in outside service are eligible for compensation. Moreover the municipality receiving help rather than the responding city is likely to be held liable for payments to injured firemen, particularly if it can be established that 'a call' for help was actually made.

"Most cities have been especially slow to develop mutual aid plans. Yet bombing or sabotage may cause a conflagration at any time. No city can control a conflagration and at the same time protect its other properties without outside help. Moreover, metropolitan areas with numerous fire departments and alarm systems are the places where 'mutual aid' is most effective if properly planned. Good practice requires a contract defining the terms under which mutual aid service will be given by each city and providing for the liabilities involved. If certain cities with serious hazards impose a heavy burden on neighboring cities, it may be wise to include a schedule of charges in the contract so that payments may be made to balance the situation.

"In the administration of a mutual aid plan, the following points should be considered: the promptness with which aid can be received; amount and type of equipment available in the area; suitability of equipment for effective aid and the maximum amount of equipment which can be moved to help a neighbor; possibility of establishing zones and adopting a plan to 'cover in' apparatus moving to another city; study of possible conflagrations and how they would be handled; arrangements for the transmission of alarms, for the use of standard hose couplings, and for the movement of equipment on first, second, and other alarms; and, finally, arrangements for holding frequent periodic drills in the different zones, these drills to approximate actual conflagrations or special emergencies.

"Several distinct advantages follow from well-established mutual aid plans. Inter-departmental alarm connections make reliance upon telephone communication unnecessary. Unauthorized calls are eliminated. The response is not a matter of trial and error but rather apparatus is sent according to signals received. Special equipment can be summoned by proper indications. 'Boundary line' difficulties are removed since running cards call out the nearest equipment no matter which municipal alarm system is used by the individual. Outside departments are not reluctant to send help because they know that their own stations will be 'covered in'

by neighboring municipalities. Finally, multiple alarms under a mutual aid plan bring together a force which can check the most dangerous fires before they get out of control."

[EDITOR'S NOTE: It is interesting to note that in the recent Lynn, Mass., apartment fire (reported in Fire Eng. **95**: 67 (Feb. '42)), the Lynn Fire Dept. recieved assistance, totaling three engines, three ladder trucks, and four engine companies, under a "mutual aid" plan, from seven neighboring towns and cities. Also a water tower was borrowed (not used) from the Boston Fire Dept.]

Supplementing Water Supply for Fire Fighting. ANON. Wtr. & Wtr. Eng. (Br.) **43**: 269 (Sept. '41). Ministry of Home Security recently announced Fire Council had approved $4,000,000 scheme for supplementing water supplies for fire fighting. Large supplies of steel tanks and special form of piping which can be laid rapidly being obtained. One simple method of providing static supplies is to use basements of bldgs. that have become untenable. Mastic asphalt is material used for waterproofing. Material arrives at site ready for application and sets hard in hour or so. Has no toxic effect on water. Little preparation work called for. Will remain in position without any internal loading coat of concrete or brickwork. Danger to health from stagnant water not overlooked. Two simple remedies present themselves. Empty and refill with fresh water. Add a little oil which will seal surface of water. Of 30 different species of mosquitoes in Britain only one likely to breed in such tanks is *Culex pipiens*, which rarely, if ever, bites human beings. Unnecessary either to change water or oil surface unless presence of mosquito larvae observed. "Wrigglers" so easily recognized by unaided eye that task of examg. suspected water may be, and has been, entrusted to intelligent child of ten.—*H. E. Babbitt.*

What Charge for Fire Protection? CHARLES H. CAPEN. Eng. News-Rec. **127**: 643 (Nov. 6, '41). Studies made many yr. ago showed that in very large cities actual cost of that part of system installed for fire protection amtd. to only 30% of total cost of physical plant, while in small towns reached as high as 70%. Most evidence to effect that little change in these ratios. One of most favored methods of charging for fire protection service so-called "in-ft. and hydrant" charge. In this, total amt. to be levied detd., charge for each hydrant (usually $10 per annum) deducted, and balance divided by no. of in-ft. (I.F.) units (main 8″ in diam. and 100′ long = 800 I.F. units) to obtain proper charge for each such unit. When addnl. mains laid, same unit charge levied. Writer believes more proper method would be to charge on basis of "in-sq.ft." (I.S.F.) units, as capac. varies more nearly as sq. of diam. Study indicated that water systems grow rapidly at first and then tend to taper off in growth when pop. approaches degree of normal satn. This suggests relationship with density of pop. Earlier studies showed that approx. relationship between density of pop. in thousands per sq.mi. (D) and I.F. units could be expressed by equation:

$$\text{I.F. units per capita} = \frac{170}{\sqrt{D}} \ldots (1)$$

Recently, in course of study of methods to inter-connect water systems in northeastern New Jersey, I.F. and I.S.F. units computed for more than 150 municipalities. Eliminating some because of factors which made their use illogical, 129 terms inserted in tabulation for computation by least squares and following equations obtained:

$$\text{I.F. units per capita} = \frac{168.9}{D^{0.509}} \ldots (2)$$

$$\text{I.S.F. units per capita} = \frac{1128.6}{D^{0.3426}} \ldots (3)$$

$$\text{Hydrants per 1,000 pop.} = \frac{28.76}{D^{0.3373}} \ldots (4)$$

Eq. (2) gives virtually same resuits as (1) and, for all practical purposes, (1)

can be used. Similarly (3) and (4) may be simplified as follows:

$$\text{I.S.F. units per capita} = \frac{1125}{\sqrt[3]{D}} \quad (5)$$

$$\text{Hydrants per 1,000 pop.} = \frac{28}{\sqrt[3]{D}} \quad (6)$$

Eqs. (5) and (6) helpful in comparing systems of various cities. In using (5), transmission main facilities should be omitted in order to obtain true picture of conditions. Ordinarily, all mains within munic. boundaries considered part of distr. system unless: (a) used in some measure to supply other municipalities; (b) no take-offs for distr. purposes; or (c) wholly used for connecting sources of supply. Plotting of I.S.F. units on chart on which insurance class or rating established by Natl. Bd. of Fire Underwriters or Schedule Rating Office are also indicated shows good correlation, particularly in classes A, B and C. As result of considerable study, following allocation of charges for protection service suggested:

	PERCENTAGE OF TOTAL FIRE PROTECTION CHARGE	
	For supply to one municipality	For supply to more than one municipality
I.S.F. units	90	65
Hydrants	10	10
Population	—	25

Advantage of such arrangement is that extensions immediately yield some revenue regardless of whether or not new consumers obtained. Application to specific case outlined. In case of supply to more than one municipality, levy of 25% of total on basis of pop. merely assures reasonable return corresponding to risk encountered with respect to size of mains.—*R. E. Thompson.*

Fire Protection Charges, 1940. Anon. W.W. Inf. Exch.—Can. Sec. A.W.W.A. **4:** B: 5: 13 (Dec. '41). Fire protection charges in member municipalities during '40 tabulated, data given, including no. of hydrants, total charge, basis of charge, amt. per hydrant and amt. per capita. Hydrant rental basis of charge in 66 municipalities and hydrant rental plus other charges in 3; annual sum paid in 18 and no charge made in 23. In communities making fire protection charge, charge per hydrant varies from $1.15 to $100.00 and avgs. $37.85, while charge per capita varies from $0.03 to $3.05 the avg. charge per capita being 73.4¢.—*R. E. Thompson.*

Hydrant Maintenance Costs. Anon. W.W. Inf. Exch.—Can. Sec. A.W.W.A. **4:** B: 3: 7 (Sept. '41). Compilation of cost of hydrant maint. in 56 Canadian municipalities, taken to include repairs, flushing and inspection. Cost varies from $0.60 to $50 and avgs. $6.11.—*R. E. Thompson.*

Fire Prevention and Fire Fighting in Chemical Plants. H. B. Suiter. Fire Eng. **93:** 603 (Dec. '40). Article contains information of value to water works. Gases in cylinders become dangerous in fires even though equipped with safety fusible plugs. Acetylene and oxygen would tend to increase intensity of fire, while others like SO_2, NH_3 and Cl provide real danger due to their irritating and poisonous fumes. Even non-poisonous fumes cause death by displacing oxygen from air. A great many liquids such as certain acids, benzol, carbon disulfide, carbon tetrachloride, bromine and metallic mercury give off dangerous poisonous fumes which greatly increase when their temps. are raised. Among commonly used flammable solvents are: acetone, alcohol (various kinds), amylacetate, benzin (petroleum ether), benzol (benzene), carbon disulfide, ether, gasoline, xylene. Precautions given for storage of various dry chems., calcium carbide—keep away from water, heats and gives off poisonous flammable gas; potassium chlorate—keep away from acids, organic matter and ammonium salts, take great care in handling as dangerous explosions liable to occur when heated or subjected to

concussion, or mixed with organic substances as cork, dust, charcoal, etc.; potassium permanganate—keep away from all organic liquids, especially glycerine and aldehydes, handle with caution as explosions can occur if brought into contact with organic or other readily oxidizable substances, dry or in soln. Dangerous accumulations of static electricity can be avoided by grounding all metal tanks, etc., to water pipe; all pulleys, shafting, belts and other moving parts of machinery should also be so grounded. Bul. 368 "Static Electricity" of U.S. Dept. Commerce, Bureau of Mines, mentioned as good source for further information. Always desirable to catch fire in its incipiency; for this purpose fire extinguishers should be placed readily accessible.—*Martin E. Flentje.*

Gas Explosions in Buildings: Their Cause and Prevention. D. J. PARKER AND C. W. OWINGS. U.S. Bureau Mines Inf. Circ. No. 7142R (Oct. '41). In past 8 yr. gas explosions in public and private bldgs. have cost 300 lives and injury to many others. Many gas consumers lack knowledge of explosive property of this fuel. Natural gas tasteless, colorless, often nearly odorless, lighter than air and nontoxic, except when CO formed by incomplete combustion. Explosive range when mixed with air is from about 4.80 to 15.00%, i.e., if natural gas percentage is below 4.80 or above 15.00, gas-air mixt. is non-explosive, most violent at approx. 9%. Gas mfrd. from coal has characteristic odor, is somewhat lighter than air and CO content runs from 6 to 12%, 10% believed avg. Concn. of CO in air of 0.05% causes slight symptoms, 0.20% definitely dangerous. Many companies furnishing natural gas add malodorants to make free gas noticeable. History given of numerous explosions caused by gas (these having occurred in both public and private bldgs.), including discussion of explosion in school at New London, Tex., in '37 resulting in death of 294. In most cases, explosion caused by trapping of escaping gas in unvented or unventilated subfloor chambers. An investigation made in Butte and Great Falls, Mont., disclosed 34 of 46 bldgs. inspected in Butte and 18 of the 20 inspected in Great Falls had unventilated subfloor chambers. Numerous recommendations made for prevention of such explosions, among them are: (1) it is poor practice to have discharges of unobstructed, open and unvented drainage systems within bldg.; (2) subdrainage pipes discharging into catch basins or sumps should be extended below water level to form water seal at all times; (3) sumps and catch basins should be vented to top and outside of bldg. and, wherever possible, should discharge directly into storm sewers—they should also be in concrete vault outside of bldg.; (4) all openings in basement walls below ground level through which pipes, conduits, cables, etc., enter bldg. should be sealed to keep gas from following them into bldg.; (5) bldgs., including steps leading to them, should not have closed underground spaces, but, where such spaces exist, floor and walls should be made as nearly gastight as possible; (6) pipes running across such spaces should be enclosed in concrete tunnels or sealed tightly where they pass through walls; (7) spaces in bldgs. below ground level should be adequately ventilated, preferably by mechanical means; (8) during constr. or inspection as to gas troubles, dark spaces should be illuminated by permissible flashlights—smoking, lighting of matches, or use of other open lights should be prohibited; (9) sewers should not be directly under bldgs. unless at least 25′ of solid strata separate top of sewer from lowest part of bldg.; (10) whenever odor of gas detected, electric switches should not be turned off or on, but electric current shut off at some safe point beyond suspected area, and matches or other sources of flame should not be allowed near rooms or areas from which odor emanates; (11) "good housekeeping" should be order of day—all inflammable materials, such as grease, oil, paints, floor dressing, turpentine, and alcohol should be kept in fireproof lockers, and oily rags and waste should be burned after use or kept in fireproof containers. —*Martin E. Flentje.*

CROSS-CONNECTIONS AND PLUMBING

The Control of Cross-Connections. G. A. H. Burn. Can. Engr. —Wtr. & Sew. **79:** 5: 15 (May '41). Cross-connection problem dealt with from every angle, with particular reference to conditions in Ontario. In addn. to cross-connections with auxiliary supplies for fire and industrial purposes, there are hazards of improperly designed plumbing fixtures and emergency arrangements at water works itself, such as auxiliary intakes from pold. sources and bypasses around purif. units. Studies by Gorman and Wolman (Jour. A.W.W.A. **31:** 225 ('39)) and by Am. Pub. Health Assn. have shown extent to which cross-connections have been involved in water-borne disease outbreaks and many prominent assns. active in san. field have adopted resolutions disapproving cross-connections unless adequately protected. Refusal of U.S. Public Health Service to certify supplies except under same conditions has aided in cross-connection elimination. Many states adopted regulations for control of cross-connections and some cities have even more stringent regulations. In Canada, Ont. adopted such legislation in '21 and Que. in '34. Protective devices include double check valves, automatic start-and-stop chlorinators, tanks with inlet above overflow level, swing joints, 4-way stopcocks and double shut-off valves on each supply with bleeders between. Arrangements which depend on zeal of employees of plant concerned are dangerous. Main features of Ont. regulations outlined and discussed. If source of private supply cannot be approved as of satisfactory quality or satisfactorily protected for domestic use, there are 3 alternatives: (1) treatment of auxiliary supply; (2) abandonment of auxiliary supply and installation of overhead tank filled from munic. system, or (3) disconnection of munic. supply. Following survey in '24, corporations with auxiliary supplies requested to make necessary changes. Strong objections received from underwriters' assns. with result that, while installation of double check valves proceeded satisfactorily, same degree of success has not been achieved in elimination of cross-connections which were in existence prior to passage of legislation. If munic. supply system reliable, elimination of undesirable cross-connection justified, but where supply not reliable may be necessary to permit cross-connections under rigid system of inspection, in which case munic. supply must be improved so as to enable elimination of cross-connections as rapidly as possible. All plants with private water supplies should be inspected regularly. Ont. regulations require that various piping systems be painted distinctive colors.—*R. E. Thompson.*

Procedure for the Survey and Elimination of Cross-Connections. B. V. BeVier. Ohio Conf. Water Purif., 20th Ann. Rept. ('40) p. 87. In previously unsurveyed cities, cross-connections will be found in practically every bldg. having private supply. Surveys should be undertaken under direction of water works supt. or other responsible official of dept. Essential that city officials be advised of reasons for such survey in order that their co-operation is assured. Newspaper publicity and form letters to plants to be visited explaining purposes of survey desirable. This should be followed by interviews with officials of plants concerned. Knowledge of size and location of services to bldg., avg. consumption, etc., should be obtained from records before visit is made. Data re: location of city lines and meters, private supplies, provisions for storage, principal uses of water, etc., should then be obtained by investigation and recorded on sketch of piping system. Approved methods for making public supply available to piping system conveying water from another source include: (1) storage facilities with inlet above el. of overflow; (2) swing elbows, (3) removable connection, provided with seal placed by water works official, which must not be used without notifying dept; and (4) 4-way plug cocks. Latter 3 cannot be used when there is elevated storage. State Dept. of Health must

approve plans for establishment or maint. of cross-connection. *Discussion. Ibid.* p. 89. R. W. FURMAN: Specific case usually necessary to arouse interest of citizens and officials in cross-connection elimination program. Large corporations usually co-operate fully in such program and principal difficulty encountered in locating small installations scattered throughout city. On 2 occasions in Toledo, cross-connections resulted in presence of objectionable amounts of ammonia in city water. In one case, area affected was about 6 blocks square, source of contamn. being beverage room, and in other, in which area of 15 blocks was involved, electro-plating establishment was to blame. In another instance, supply to factory at end of remote 8" main suddenly acquired color of strong tea and anal. disclosed presence of potassium dichromate and 7,500 ppm. calcium chloride. Owing to short duration, 3 such contamns. occurred before trouble was located in adjoining coal yard at which calcium chloride was applied to coal for dust prevention by means of compressed air spray from large closed tank. New employee had neglected to close valve in water supply line. Survey has been made as part of W.P.A. project, some 150 plans having been prepared and changes found necessary in almost every case, and work is being continued by full-time engr. of water dept. *Ibid.* p. 91. W. R. LADUE. Elimination of cross-connections in Akron handled by div. responsible for large industrial meters. Before elimination program commenced, about 20 engrs. from larger companies invited to water dept. office for discussion of problem. Policy worked well and of 50 cross-connections discovered, all but 2, now in process, have been eliminated. Costs involved have ranged from a few dollars to $30,000. In one of remaining cases, cost may be $100,000. Regulations of dept. regarding cross-connections given. Largest companies in city expended as much as $4,000,000 on private supplies. Close inspection maintd. on services where cross-connections have been broken and it has been found necessary to make such inspections at irregular intervals so that consumer will not know when to expect visit. Penalty of temporarily disconnecting city supply has corrected tendency on part of some to restore connections. Meter and turn-off men required to make occasional inspections for unauthorized connections and water is not supplied to new services until piping has been inspected for possible cross-connections.—*R. E. Thompson.*

A Check on Cross-Connections. LEONARD A. BERGMAN. W.W. Eng. **94:** 1137 (Sept. 10, '41). In response to request of N.Y. State Dept. of Health, Div. of Water of Buffalo organized and conducted surveys to det. extent of cross-connections in city. Since Feb. 3, '41, 640 inspections made, 131 cross-connections found, and 103 corrected in accordance with state san. code. Crew consisting of chief of inspection staff, one master plumber, and another man experienced in such surveys, makes inspections in presence of plant's maint. personnel during working hours of plant. In those sections where violations less probable, affidavit form presented in lieu of inspection. When this signed, responsibility placed upon consumer. State code places responsibility, in seeing that cross-connections with non-potable supplies be prevented or eliminated, on officials in charge of potable supply, which usually is public supply. Aim on all auxiliary supplies to have each supply independent of other by eliminating all phys. connections with city water. Found that: Most of violations caused by ready-to-serve city water supply being connected to secondary supply for emergency purposes without proper protection against contamg. public water system. Approval for cross-connections granted only when each supply made independent of other.—*P.H.E.A.*

Cross-Connections to Steam Boilers. R. F. GOUDEY. W. W. & Sew. **87:** 365 (Aug. '40). Program for elimination of cross-connections to steam boilers at Los Angeles described. Proved successful. Practical, economic, and san. objections to boiler cross-connections discussed quite fully; practical methods for their elimination given.—*Ed.*

Plumbing Systems for Defense and Low-Cost Housing. ANON. Architectural Rec. **90:** 91 (Nov. '41). Presents brief simplified safe stds. for plumbing practice advocated by U.S. Dept. Commerce, Natl. Bureau Stds. (BMS 66). Purpose of latter to reduce quants. of materials required, hence costs. Apply only to 1- and 2-story residential bldgs. Assumes adequate supply of potable water and satisfactory sewage disposal facilities available. Pipe-size selection should be governed by no. and type of fixtures supplied; length of piping and friction loss of fittings; probable reduction in diam. by corrosion, depending on water anal. and piping materials. Materials selection should be detd. by anal. of water. Use ferrous piping for slightly and moderately corrosive water in cold-water systems, and for slightly corrosive water in hot-water systems. Use nonferrous or lined piping for corrosive cold water, or moderate to corrosive hot water. Lead piping not to be used until detd. that no poisonous lead salts produced by contact with specific water. Avoid electrolytically productive combinations. Similar details given for installation and hot-water supply system. Points amply illustrated with tables and diagrams. Drainage diagrams shown and 21 definitions given. Drainage piping selection, installation and practice elaborated upon under headings: soil and waste lines (traps, cleanouts, piping); installation (support, changes in direction, drilling and tapping, protection from breakage, joints and connections, obstructions); vent piping diagrams and definitions.—*Ralph E. Noble.*

State Plumbing Code, Maine. Dept. of Health & Welfare ('40). New plumbing code comprises amendments to rules and regulations relating to plumbing adopted by Advisory Council of Health and Welfare, approved Sept. 26, '34, and amended Aug. 26, '37, as provided by Public Laws of '33. Regulations to be known henceforth as state plumbing code. Code complete, defining materials and practices of plumbing and requiring adherence to detailed specifications for installation of fixtures and piping, whereas former regulations provided only for inspections, permits, and licensing of plumbers. Pilot drawing of Maine plumbing included.—*P.H.E.A.*

Control of Plumbing and Raising of Plumbing Standards. W. E. JAMESON. Tex. W. W. Short School. **22:** 29 ('40). Plumbing deals with health not bldg. constr., and enforcement of codes should be vested in board of health. In smaller towns with no inspectors, ordinances not enforced due to political reasons.—*O. M. Smith.*

Hospital Plumbing. ANON. Sanitarian. **3:** 90 (Sept. '40); Weekly Bul., Ore. State Board of Health (June 18, '40). Survey of Ore. hospitals revealed many having hazardous plumbing discrepancies of various kinds. Complete remodeling out of question, but water supplies can be protected by making necessary changes and including such fixtures as vacuum breakers. Air gaps will be provided and cross-connections eliminated. Polg. materials peculiar to hospitals discussed in relationship to their effect on drinking water. Special fixtures included in hospital equip. which lend themselves readily to plumbing errors included in report, and corrections necessary given. Air-conditioning and refrigerating equip. and water-operated elevators also considered. Vents, traps, and floor drains, unless installed properly and in correct size, aggravate problem. Fixtures should not permit even slightest possibility of back-siphonage. Inspection and correction of the Ore. maternity homes and hospitals will insure safety of mothers and babies utilizing institutions.—*P.H.E.A.*

What Size Pipes? ANON. Domestic Eng. **159:** 54 (Feb. '42). Condition of piping and length of service important factors in detg. pipe sizes for water distr. systems in bldgs. BMS-79 report says: because of many variable factors, not practical to specify min. diam. requirements for water supply pipe lines. Except for fixture branches, sizes for any bldg. should be detd. from estd. peak or max. demand therein. Estd. pipe capacs. should be based on particular conditions including available service

pressure, el. of highest fixtures above street main, and avgd. est. of effects of water on capac. of pipes in service. Min. sizes of fixture supplies standardized for Federal use (Fed. Spec. WWP-541a), logically applying to fixture branch connecting to fixture supply. Ests. of total max. water demand for any no. of fixtures, same or different kinds, made by applying relative load-producing values for different fixtures and occupancies, and computing probability of overlapping demands; apparently with greater accuracy than that of bldg. supply systems capac. after several yr. services. For complicated bldg. water supply systems, design or piping layout and selection of material and pipe sizes should be delegated to experienced engrs. Present knowledge incomplete regarding effects of different waters on pipe capacs. in service for accurate est. of bldg. water supply systems capacs.—*Ralph E. Noble.*

LABORATORY METHODS—EQUIPMENT AND APPARATUS

On the Precision of Estimates From Systematic Versus Random Samples. James G. Osborne. *A Discussion.* Science. **94:** 584 (Dec. 19, '41). Sampling eff. increased by greater use of stratified random selection. Knowledge of pop. and judicious choice of strata sampled often permits reductions in variation incident to ests. of pop. parameters. Eff. gains limited, however, by (1) extent of stratification, (2) size of sample and addnl. cost of selecting strata observations, and (3) requiring at least 2 observations selected at random in each stratum sampled. Latter (3) apparently inconsequential but has serious effect. U.S. Forest Service must make many ests. in areas, then est. latter. Uses line-plot and strip methods of sampling, i.e., evenly spaced plots along evenly spaced lines observed or, evenly spaced strips used as plots. Such selection does not meet requirement of independence and randomness, or provide valid est. of sampling errors when random sampling formulas used. Important, therefore, to know effect on precision of sample ests. by requiring at least 2 observations selected at random in each stratum. To answer question, tests of cover type ests. resulted in eff. gains, often more than 100%, due to fact great bulk of pops. in biological and social-science investigations not segregated into well-defined strata homogenous within borders, but vary continuously as els. or fertility levels in field. Sampling in many pops. in place or time reduces to estg. ordinates, or detg. integral of single-valued continuous curve. Thus, uniformly spaced observations will yield better representation of curve than will those restricted only to extent when abscissae range of curve divided into $\frac{n}{2}$ equal parts, 2 of n observations fall in each. Gain in accuracy, as measured by expected variation among systematic sample totals or means, arises also from usually high correlation among them. Thus, when results of single sample, so selected, available, results of any other such sample predictable with considerable precision. Author gives technical (math.) procedures to produce an est. of precision of such prediction.—*Ralph E. Noble.*

Particle Size Determination by Sedimentation. Karl Kammermeyer and J. L. Binder. Ind. Eng. Chem.—Anal. Ed. **13:** 335 (May '41). Sedimentation methods permit high deg. of differentiation between particle sizes of granular material when ordinary screen anal. does not suffice. Where change in pressure measured with manometer as suspended material settles out, difficulties arise in reading meniscus and evaluating data, leading to appreciable inaccuracies. Method also fails for large particle sizes. Apparatus here described permits suspension of particles as large as 32-mesh (ca. 500 microns diam.) in S.A.E. 40 oil as suspending medium. Settling tube large enough to permit introduction of motor-driven stirrer. Spoon gage, made by elongating thin-walled tube and then flattening on one side, thin enough

so that pressure difference of few mm. of Hg noticeably deflects pointer, movement of which amplified by optical system. Pointer deflections converted to pressure changes by calibrating gage. After constructing accumulation curve, particle size distr. curve obtained in usual manner. Since given liquid height always corresponds to definite position of pointer, final position, corresponding to complete settling, can be calcd. after bulk density of material detd. Experience of authors shows that apparatus more convenient in use than usual type, and particle sizes can be measured with it that are impossible to measure with manometer type.—*Selma Gottlieb.*

An Apparatus for Obtaining Water From Different Depths for Bacteriological Examination. C. H. Mortimer. J. Hyg. (Br.) **40:** 641 ('40). Describes apparatus used for taking samples of lake water from various depths for bact. exam. Sampling bottle, filled with air, clamped into framework and provided with rubber stopper carrying one long and one short tube. Free end of short tube bent into double loop to prevent entry of water as bottle drawn to surface. Before bottle lowered, ends of tubes closed by bent glass link. When bottle lowered to desired depth, messenger weight sent down cable releases spring which pulls out glass link and allows water to enter bottle through the long tube and air to escape through short one. Second bottle to obtain sample for detn. of dissolved oxygen may be fitted to apparatus.—*W.P.R.*

A Separating Buret. D. B. Iokhel'son. Lab. Prakt. (U.S.S.R.) **15:** 11: 31 ('40). Buret for quant. detns. in which aliquot part of soln. anald. consists of 100-ml. graduated cylindrical tube with ground stopper, 0.1–0.2-ml. scale divisions and stopcock at 60–65-ml. level. Good results obtained in detns. of calcium, magnesium, magnesium oxide, alumina, etc., as well as in detns. of hardness in drinking water according to method of Pfeifer-Wartha. In this detn., neutralize 50 ml. of water, heat, add Pfeifer's reagent, heat, cool, transfer into the separating buret, add distd. water to 100 ml. and shake. Let ppt. settle and decant 50 ml. of clear soln. Settling saves time and is more accurate than filtration.—*C.A.*

Modified Photoelectric Photometer for Colorimetric Determinations in Water and Sewage Laboratories. William D. Hatfield and George E. Phillips. Ind. Eng. Chem.—Anal. Ed. **13:** 430 (June '41). Photoelectric photometers commercially available costly and not well adapted to long tubes needed in water and sewage work. Models described, of vertical beam type, can be built for $26 for single-cell unit, or $60 for balanced cell unit, more convenient in operation. Results equally satisfactory with both models. Complete directions for constr. given, including wiring diagrams and description and cost of parts. Instruments calibrated for each type of detn. with color standards prepd. according to *Standard Methods*, resulting transmission curves replacing all color standards. Photometer found suitable for detn. of turbidities over 10 ppm., pH, ammonia, nitrite and nitrate, ferrous and total iron, residual chlorine and even to detn. of iodine in D.O. and B.O.D. tests.—*Selma Gottlieb.*

A Slide Rule for Calculating Degree of Oxygen Saturation in Water Samples. A. A. Hirsch. Sew. Wks. J. **12:** 1124 (Nov. '40). Slide rule for computing percentage oxygen satn. of water when dissolved oxygen, temp., salinity, and barometric pressure known. Scales reproduced in such form that they may be photostated and glued to inexpensive slide rule for convenient use.—*P.H.E.A.*

Laboratory Studies of Methods for Cleansing of Eating Utensils and Evaluating Detergents. F. W. Gilcreas and J. E. O'Brien. Am. J. Pub. Health. **31:** 143 (Feb. '41). In preliminary studies, glasses heavily contamd. with *Esch. coli*, or haemolytic streptococci, found to be practically sterilized by washing at 100°–110°F. and rinsing at 170°F. without chem. treatment. Most of paper taken up with description of apparatus and technique to test eff. of action of detergents. Microscopic slides

used instead of drinking glasses, metal tanks resting on elec. hot plate used for washing and rinsing operations. Rocking device operated by elec. motor used. Two media for testing influence of liquid soils used, one mainly protein and fat and other fats and oils. Cleanliness of slides after action of detergent measured by a photoelec. colorimeter. Ratio of median reading of washed slides to that of control slides taken as "cleansing index" of detergent. Paper must be consulted for method of working and exact details. 36 detergents studied, including proprietary products and basic detergent materials, and using both liquid soils. Waters of various hardness employed. Water temps. used for rinsing were 2 min. at 120°F. and 1 min. in clean water at 160°F. Authors suggest that technique enables detergents to be evaluated and std. technique should be established.—*B.H.*

Researches of Mellon Institute 1940–41. ANON. Am. Chem. Soc.—News Ed. **19:** 392 (Apr. 10, '41). *Progress in Research on Waste Pickle Liquor Utilization.* Fellowship of Am. Iron and Steel Inst. (W. W. Hodge, advisory fellow) studied chiefly more promising process for treating waste pickle liquor. Lack of adequate markets for recovered iron salts drawback to many proposed treatment processes. Application of copperas and lime in water purif. and of chlorinated copperas, ferric sulfate, ferric chloride and certainly recently developed "ferri-gels" in sewage treatment appear to be receiving increased favorable attention. Fellowship has cooperated with san. engrs. of U.S. Public Health Service and with state and munic. health organizations. Work of fellowship has resulted in better pickling operations in many steel companies, with better acid utilization and smaller quant. discharged as waste, and in further studies on waste treatment by steel companies themselves. Estd. annual production of corrosive waste pickle liquor in U.S., 500 to 800 mil.gal. *New Plastic Parts for Meters.* Pittsburgh Equitable Meter Co. fellowship (R. L. Wakeman) has developed special laminated phenolic-type water-meter disk for hot-water meters and has studied operation of hot-water meters. *Nutrition and Dental Caries.* Fellowship of Buhl Foundation has concluded that pre-eruptive influences are dominant in subsequent susceptibility of teeth to caries. Fluorine in diet of rats during pregnancy and lactation produced teeth in young with increased resistance to caries. Enamel not mottled. Fellowship introduced new methods of causing experimental mottled enamel in molars of rats by direct feeding of fluorides to sucklings. [Details not given.] Fluorine plays prominent part in caries prevention in pre-eruptive nutrition of rats. Supporting data from human caries, establishing, with certainty, mode of action of fluorine and delimiting dosage, needed before such a practice can be introduced successfully.—*Selma Gottlieb.*

Laboratory Service for the Water Works Systems of Ontario. A. E. BERRY. Can. Engr.—Wtr. & Sew. **79:** 6: 66 (June '41). Provincial dept. of health operates extensive lab. service for examn. of both public and private supplies. In addn. to main lab. in Toronto, 6 branch labs. perform bact. examns. Sterilized bottles in mailing cartons provided, samples being forwarded without icing. Routine examn. consists of detg. coliform bacteria only. To avoid use of technical terms as much as possible, results reported as smallest amt. of water contg. organisms. Arbitrary classification also employed—Grade A being colon-free and D contg. heavy poln. Exptl. lab. maintd. for special investigations and for aiding municipalities in their problems. Owing to widespread services provided, municipally owned labs. not numerous in Ont.—*R. E. Thompson.*

Laboratories of the City of Toronto Water Works Department. NORMAN J. HOWARD. Can. Engr.—Wtr. & Sew. **79:** 6: 68 (June '41). Lab. placed in commission in '10 and by '40 no. of samples examd. annually 33,833. Chem. tests made on raw water every 3–4 hr. for taste control and water entering distr. system examd. bacteriologically at 6-hr. intervals. In addn., complete

bact. examns. made of treated and untreated water, tests made including no. of bacteria growing on std. agar and on MacConkey's bile salt agar at 37°C. and examns. for coliform bacteria. Bact. std. aimed at is coliform bacteria absent in 100 ml. In '40, 96% of city water samples neg. in 100 ml., and 99.7% neg. in 10 ml. Residual chlorine tests made at de-chlorination station every 30 min., and water tasted at same intervals. Great deal of research work conducted. Annual cost of operation approx. $15,-000.—*R. E. Thompson.*

BACTERIOLOGY

Papain Digest Media and Standardization of Media in General. Igor N. Asheshov. Can. Pub. Health J. **32:** 468 (Sept. '41). Use of papain, in form of dried juice of Carica papaya, as digestive agent in prepn. of media for bact. use described. To 4 l. distd. water, add 1 kg. minced beef or veal and 10–15 g. papain which has been ground into paste with 1–2 ml. glycerine and suspended in 20–50 ml. water. Adjust to approx. pH 7 with ammonium hydroxide and maint. mixt. at this pH value and at temp. of 60–65°C. for 3 hr. Occasional control pH tests only, necessary, as shift to acid side occurs only during first hr. Filter through "agar" paper, adjust to pH 8 with ammonium hydroxide and heat in autoclave at 115°C. for 20 min. to separate phosphates and coagulable substances. Undigested material retained on paper does not exceed 4% of meat used. Cool, filter through "agar" paper, adjust pH to 7 with hydrochloric acid and autoclave in convenient quantities. Concn. of broth so prepd. detd. by method based on detn. of oxygen consumed value of water. To diln. of broth, add std. soln. of potassium permanganate, boil 5 min., add equivalent amt. of std. oxalic acid and titrate back with potassium permanganate. Results are expressed as "% oxidizable matter," i.e., grams of oxygen required per 100 ml. Concn. of broth prepared as above varies from 1.2 to 2.5%, depending on qual. of meat used. For nutrient broth and agar, diln. to 0.5–0.75% and 0.75–1.0%, respectively, of "oxidizable matter content" without addn. of nutrient substances gives satisfactory medium. Composition of media may be varied for different bacteria by altering pH, temp. and period of digestion. Addn. of liver, about 25% by wt., to meat improves medium for many organisms.—*R. E. Thompson.*

Factors Influencing the Preparation of the "Tetrathionate Agar Medium (Schustoma)" and a New Culture Medium for Isolating Bacillus Typhosus. K. Ryu Shyuku. J. Oriental Med. **34:** 305 (*English abstract, p. 20*) ('41). Best technique recommended to mix iodine soln. (20 g. iodine, 25 g. potassium iodide in 100 ml. water) with thiosulfate soln. (50 g. sodium thiosulfate—$Na_2S_2O_3 \cdot 5H_2O$—in 130 ml. water), as quickly as possible and immediately to add mixt. to agar medium. Six formulas recommended contain 100 ml. agar medium, 1.5–2.5 ml. iodine soln. and 4–8 ml. thiosulfate soln. Author's own culture medium contains 100 ml. agar medium, 5 ml. bile and 4 g. $Na_2S_2O_3 \cdot 5H_2O$, which is as good as "Schustoma's" tetrathionate medium for obtaining selective growth of *Eberthella typhosa* in presence of *Esch. coli.*—*C.A.*

Mechanism of the Selective Action of Eosin-Methylene-Blue Agar on the Enteric Group. E. S. Wynne, L. J. Rode and A. E. Hayward. Stain Tech. **17:** 11 (Jan. '42). Actual mechanism of lactose- and non-lactose-fermenting organism differentiation on E.M.B. not reported in literature. Color of colon forms on E.M.B. depends on: (1) reaction of eosin with methylene blue to form acidic or neutral dye compd., and (2) production of sufficiently low pH by lactose-fermenting organisms to extend dye compd. taken up by individual cells. Non-lactose-fermenting organisms not colored because compd. not taken up when reaction alk. Occasional colonies may be blue due to formation of relatively high pH causing slight dissociation of

compd. to allow independent staining by methylene blue. Under acid conditions, compd. composed of 1 molecule of methylene blue and 1 of eosin. Color of acid-producing colonies on E.M.B. referable to actual staining of individual cells with this compd.—*Ralph E. Noble.*

Replacing Endo Medium With Rosolic Medium. M. G. KICHENKO AND N. G. KICHENKO. Lab. Prakt. (U.S.S.R.) **16:** 5:6 ('41). For prepn. of rosolic medium, take 20 g. Arkhangelsk agar-agar, clarify it with egg white, add 10 g. lactose and 50 ml. ox bile, add 1 l. distd. water and adjust to pH 7.2–7.5. To 1 l. of medium, add 2.5 ml. 1.5% alc. bromothymol blue soln. and 2 ml. 5% alc. rosolic acid soln. (not older than 30 days). Reaction takes place at time of adding rosolic acid; medium whitens at surface of contact, but after mixing, color of medium changes from green to brown. At pH less than 7.2, medium has grayish tint; above 7.5 it is more red. Pour medium into test tubes and sterilize in autoclave at 112° for 20 min. Medium does not change on standing even in daylight for several mo. Colonies oval-shaped. *Esch. coli* yellow on yellow background and *Esch. paracoli* black on red background. Results show that medium is as effective as Endo medium. Suppresses growth of saprophytes, has no effect on growth of *Esch. coli* and can be kept for considerable length of time. In absence of bromothymol blue, medium can be prepd. with rosolic acid in same proportion. Such medium possesses gold-pink color. Under influence of acid-forming bacteria (*Esch. coli*) color changes to yellow and colonies remain yellowish white. Base-forming bacteria change color of medium and colonies to intensive pink.—*C.A.*

A New Nutrient Medium for Bacteria With Special Requirements. H. O. HETTCHE AND W. ZISCHG. Arch. Hyg. (Ger.) **123:** 291 ('40). Discusses value of various nutrient media suggested for replacing media contg. meat. Tests on use of media made from skim milk, dried milk powd., casein powd., soya bean meal and "bread water" for culture of coliform bacteria, streptococci, pneumococci, diphtheria bacteria and meningococci, described; results shown in tables. Whole milk more satisfactory than skim milk. Good results obtained with bread water, but casein powd. and soya bean meal not satisfactory. Authors then tested two new media made from prepn. of soya bean meal, sold under name of "Edel-Soya," and from pea meal. In prepn. of soya bean medium, meal first digested in alk. medium and then, if desired, in acid medium. Single alk. digestion sufficient for pea meal. Growth of bacteria tested in soya bean medium as good as in meat broths. Pea meal also good but had disadvantage that it could not be heated in autoclave.—*W.P.R.*

Cellulose Derivative Substitutes for Agar. ANON. J. Am. Chem. Soc.—News Ed. **19:** 1156 (Oct. 25, '41). While research on agar production from British seaweed has shown larger supplies obtainable, new cellulose derivative usable as emulsifying agt. in place of agar-agar, gum acacia, tragacanth, and alk. stearates, has been prepd. Forms colloidal neutral soln. with water, and reported light and temp. stable. Film remaining after evapn., insoluble in usual cellulose solvents. — *Ralph E. Noble.*

Can Silica Gels Be Used as a Substitute for Agar in Bacteriological Culture Media? K. W. CLAUBERG. Zent. f. Bakt. (Ger.) **147:** 1: 75 (Apr. 4, '41). Use of silica gels to solidify media not new. Of formulas tried by author, following gave best results: (1) glycerine 6 parts, asparagin 0.4 parts, distd. water to 100 parts, adjusted with NH_4OH to pH 7.5; (2) yeast extract broth, pH 7.5; (3) water-glass (sodium silicate) cp.; (4) phosphoric acid, 25%. Mix 3 parts of (1), 6 parts of (2) and 0.6 parts of (3). Adjust to pH 7.2 with (4). Ingredients must be mixed in cold and plates poured quickly. About 0.27 parts of (4) required. Enriching substances may be added. Medium is improvement on those previously described, and though certain deficiencies exist, gives satisfactory growth of intestinal organisms, staphylococci and anaerobes.—*B.H.*

Reclamation of Agar. Hilda G. MacMorine. Can. Pub. Health J. **33:** 39 (Jan. '42). Melted agar, after removing blood or serum if present by coagulating with heat and filtering through cheesecloth, allowed to set in glass cylinders about 6" in diam. and cut into slices about 0.5 cm. thick, which are washed with cold tap water first by decantation and then by pouring water through the slices held in cheesecloth-lined funnel. Agar then melted and carbon black added to decolorize and remove addnl. broth factors, and mixt. filtered through hot Buchner funnel, lined with filter paper and hot paper pulp. To resulting clear, colorless soln. are added potassium oxalate and potassium carbonate and mixt. autoclaved 1.5 hr. at 250°F., filtered and poured into 2 volumes of cold acetone with vigorous stirring. Pptd. agar, fairly granular, filtered off in Buchner funnel, washed with acetone and spread on paper to dry. When acetone evapd., product ready for use. Ethyl alcohol may be used as precipitant but ppt. more colloidal and more difficult to filter. Recovery about 75%. Recovered agar as light in color as commercial agar, gives hardness only slightly inferior and not bactericidal.—*R. E. Thompson.*

Progress in the Standardization of Stains. *No Further Certification of Gentian Violet.* H. J. Conn. Stain Tech. **16:** 141 (Oct. '41). Beginning Jan. 1, '42, Biological Stain Com. will no longer certify any dye under name, "gentian violet." Must be labeled "crystal violet," "methyl violet 2B," or so on. After name, in small type, may add statement: "Formerly sold as gentian violet." Users should specify crystal violet for bact. work, and for histological work where deep blue-violet is required; methyl violet 2B in histological procedures where reddish shade desired.—*Ralph E. Noble.*

A Stabilized Spore Suspension for Disinfection Tests. George R. Weber and Max Levine. (*Published in abstract only.*) J. Bact. **43:** 53 (Jan. '42). *B. metiens* spores (170 × 10^6/ml.) suspended in Butterfield's formula *C* water and stored at 10°C. showed no appreciable change in resistance to Cl_2 or chloramine solns. over 2 yr. Times required to kill 99% of spores exposed at 20°C. (pH 7) to 25 ppm. available Cl_2 as hypochlorite and chloramine, 3 min. and 89 min., respectively, when freshly prepared spore suspension used. Killing times for same suspension 2 yr. later, 3.2 min. with hypochlorite and 91 min. with chloramine. Difference in killing times of fresh and old suspensions well within limits of error of duplicate detns.—*Ralph E. Noble.*

The Selective Bacteriostatic Effect of Slow Oxidizing Agents. W. L. Mallman, W. E. Botwright and Elbert S. Churchill. J. Infec. Dis. **69:** 215 Nov. -Dec. '41). Numerous selective media available contg. such dyes as gentian violet and brilliant green that inhibit growth of gram-pos. organisms while allowing development of gram-neg. ones. In this report, demonstrated that slow oxidizing agents, potassium dichromate and sodium azide, exert bacteriostatic effect on gram-neg. bacteria. By using appropriate dilns. of these 2 agents, possible to suppress growth of gram-neg. yet allow development of gram-pos. bacteria. Gram-pos. cocci, particularly streptococci, appear to tolerate slow oxidizing agents to greater extent than gram-pos. spore bearers. Slow oxidizing agents in nutrient media can be used successfully as selective agents to allow growth of gram-pos. bacteria from mixts. of gram-pos. and gram-neg. organisms. —*Ralph E. Noble.*

Antagonistic Relations of Micro-organisms. Selman A. Waksman. Bact. Rev. **5:** 231 (Sept. '41). Comprehensive article reviews subject in following sections: survival of pathogens in soil and water; symbiosis and antibiosis; antagonistic effects of bacteria, spore-forming and non-spore-forming, and actinomycetes; antagonistic effects of fungi; antagonistic action of animal forms; chem. nature of antagonistic substances; disease control with antagonistic micro-organisms; retrospect; and references (373). Portions of interest to water sanitarians follow: Dis-

ease-causing microbes find their way into soil and water in large nos. in excreta or dead and infected residues. With few exceptions, organisms pathogenic to man and animals do not remain alive in soil and natural waters long. Typhoid and dysentery bacteria, known to contam. watersheds and water supplies, sooner or later disappear. No one now questions rôle of soil as carrier of disease-producing agents or as cause of epidemics. Rapid disappearance of disease-producing bacteria may be due to several factors, including: (1) unfavorable environment; (2) lack of sufficient or proper food; (3) destruction by predacious agents, such as protozoa and other animals; and (4) destruction by various saprophytic bacteria and fungi considered antagonists. Frankland first established that typhoid bacterium may survive in sterilized pold. water or in pure deep well water 20–51 days, but that it dies out rapidly in 9–13 days in unsterile surface water. Jordan, et al., found *Eberthella typhosa* survived in sterilized tap water 15–25 days, against 4–7 days in fresh water; it died off even more rapidly (1–4 days) in raw river or canal water. Deg. of survival in water found to be in inverse ratio to deg. of contamn. of water, saprophytic bacteria being directly responsible for destruction of pathogen. Freshly isolated organisms survived shorter time than lab. cultures. Higher temps. more destructive than lower ones. Presence of certain bacteria in water often found to hinder survival of *E. typhosa*. When *Pseudomonas aeruginosa*, present in drinking water, however, may not be accompanied by any other bacteria. Media inoculated with this organism and with *Esch. coli* gave, after 13 days cultivation, only cultures of former; yet, two organisms can coexist in sterilized water. *Vibrio cholerae* does not survive long in fresh water, although long enough to cause occasional epidemics. Typhoid and paratyphoid bacteria found very shortlived in sewage sludge, 99% being reduced after 6 hr. treatment of activated sludge. Marked difference in survival of different strains. One died off rapidly, two died in 8–10 days, and one survived 13. Addn. of typhoid bacteria to well-moistened and cultivated soil brings about their rapid destruction. Same phenomenon occurs when culture of these is added to that of soil microbe. *Esch. coli* rapidly crowded out by other organisms in manure piles and in soil. Dysentery and typhoid organisms disappear rapidly in sea water, 12–16 hr. Paratyphoid organisms have been found to survive 21–23 days. Sea water appears to contain agent, other than salts, exerting bactericidal effect. *Esch. coli* may lose property of fermenting sugar when grown together with paratyphoid bacteria, illustrating "functional antagonism." Antagonism may be either one- or two-sided, i.e., when only one bacterium represses another, which is not antagonistic to it, or when each organism represses the other. One-sided antagonism may become two-sided under certain conditions of culture. *Esch. coli* antagonistic to *E. typhosa*. If latter inoculated into medium somewhat earlier than former, however, reverse true. In '01, Frost established that several bacteria are able to exert marked antagonism against *E. typhosa*. *P. fluorescens* exhibited strongest effect; *Proteus vulgaris* acted more rapidly, but active substance did not diffuse so far into medium. Filterable and thermostable antagonistic substances produced; their action varied with temp., most pronounced at 37°. At ice-chest temp., action so delayed that pathogen was able to develop. Frost believed this offered possible explanation of fact that when water supplies become contamd. in cold weather their power of producing infection retained longer than in warm. Numerous non-spore-forming bacteria shown to antagonize other bacteria. Particular attention paid to pyocyaneus and fluorescens groups. Much consideration also given to members of colon-typhoid group. Wathelet found, in mixed culture, colon organism gradually replaces typhoid. Chatterjee noted typhoid and paratyphoid bacteria fail to multiply when inoculated into media in which colon bacterium previously grown. Occurrence of slow lactose-fermenting *Esch. coli* strains in stools, as well as inhibitory action found in certain stools

seeded with *E. typhosa*, ascribed to antagonistic action of former. Different strains *Esch. coli* appear to repress typhoid organism to different extent, freshly isolated strains being more active than stock cultures. Young, actively growing cultures of *E. typhosa*, however, inhibit growth of *Esch. coli*, older cultures being non-antagonistic. Many other interesting effects on coliform organisms by other bacteria or their products cited.—*Ralph E. Noble.*

The Effect of Culture Environment on Results Obtained With the Dilution Method of Determining Bacterial Population. George M. Savage and H. O. Halvorson. J. Bact. **41:** 355 (Mar. '41). Dilution method early employed by Phelps for estimating *Esch. coli* pops. in drinking water. Interpretation of results from such dilutions not possible without conversion tables of probable pop. values provided by later workers. Such values derived statistically from experimentally obtained "codes," which express numbers of sub-culture tubes showing growth from each of 3 successive 10-fold dilutions. Uncommon codes occur quite frequently when unfavorable culture media used for subculturing bacteria. Tend, however, to become common codes after long periods of incubation. Appearing uniformly is gradual type, in which change from all growths to no growths spread over 4 or more dilutions. Appearance of uncommon codes, gradual type, should serve as warning that medium being used for sub-culturing may be unfavorable for growth.—*Ralph E. Noble.*

Water Bacteriology and Chlorine Residuals. John W. Krasauskas. 15th Ann. Conf. Md.-Del. Wtr. & Sew. Assn. ('41). p. 35. Low typhoid death rate and relative scarcity of large epidemics of intestinal disorders traced to water supplies lulled many operators into false sense of security. Low typhoid rate due to: (1) using Cl_2 for sterilization and (2) detection and isolation of typhoid carriers by state, munic. and county health authorities. Complexity of bacterial reaction to chem. disinfection well known, so that complete reliance on Cl_2 residual as indicator of safe water supply dangerous. As this test is important for efficient control of filtration plant, should be co-ordinated with complete bact. examn. Cites reference reporting that in many cities of 2,500–300,000 pop., record-keeping grossly inadequate and no provision made for bact. examn. of water supply. Many operators feel bacteriology too complicated, therefore neglect making such tests. Academic study required but operator with good common sense can make bact. tests, especially with co-operation of health dept. Bact. and Cl_2 residual tests both imperfect but essential. Latter rapid, former slow. Cites reference to study of organisms isolated from chlorinated supplies. In U.S. labs., ortho-tolidine test used for qual. detns., iodometric test for quant. work. Yellow color production in former influenced by nitrites, ammonia and manganese. Sensitivity decreases as Cl_2 concn. increases. Colored waters cannot be tested. Iodometric test less sensitive than ortho-tolidine but nitrites and manganese do not interfere. Nitrates and ferric salts do, however, and incorrect results occur at small Cl_2 concns. In di-methyl-para-diamin test no interference experienced from nitrites up to 5 ppm. and iron up to 1 ppm. With this reagent, color fades rapidly if Cl_2 greater than 0.7 ppm.—*Ralph E. Noble.*

The Effect of a Vacuum on the Destruction of Bacteria by Germicides. A. J. Salle and M. Korzenovsky. (*Published in abstract only.*) J. Bact. **43:** 52 (Jan. '42). Tests made to det. effect of vacuum on destruction of bacteria by germicidal agents in soln. and in gaseous state. Killing diln. of germicide under atmospheric conditions and in vacuum, same. Removal of air from liquid with possible increase in penetration did not increase eff. of germicide. Entirely different results obtained when gaseous germicides used. Bacteria placed in center of cotton rolls or embedded in fine sand not killed by action of gas under atmospheric conditions but easily destroyed in presence of vacuum. In absence of latter, gas acted as surface

disinfectant whereas in its presence, material easily penetrated by gas. Organisms tested included *Esch. coli*, *Eberthella typhosa*, *Staph. aureus*, *Ps. aeruginosa*, *Str. faecalis*, *B. mycoides*, *B. subtilis*, and *B. anthracis*. Organisms subjected to high vacuum, then appropriate amt. of gas introduced and sterilizer held under partial vacuum for 30 min.—*Ralph E. Noble.*

The Effect of Temperature on the Self-Purification of Water With Special Reference to Bacteriological Conditions. K. VIEHL. Z. Hyg. InfektKr. (Ger.) **122:** 81 ('39). Refs. in literature on effect of temp. on biol. purif. of sewage and on self-purif. of water are contradictory. Lab. expts. in which 2 liters of river water added to 9 liters of settled sewage and incubated showed that at higher temps. no. of bacteria sewage reached max. and then decreased more rapidly than at lower temps. At beginning of expt., typical *Esch. coli* found, but as self-purif. proceeded, atypical forms appeared. At room temp. all ammonia converted to nitrite in 24 days, and nitrate formation completed in 5 wk. At 2.7°C. ammonia did not begin to disappear until 12th wk. and nitrite never present in more than traces; by 15th wk. nearly all nitrogen converted to nitrate. Thus appears that nitrate-forming organisms more tolerant to low temps. than nitrite-forming organisms. In expts. on self-purif. in polluted river water, samples taken regularly from inlet and outlet of Elster reservoir, from Elster R. at Bösdorf, and from Pleisse R. at Trachenau. No. of bacteria in reservoir vary inversely with temp. of water rather than with flow. In Elster, fluctuations in no. of bacteria even greater than in res.; lowest no. found in summer. Similar variations in Pleisse. At all sampling stations, condition of water, as indicated by B.O.D., worse in winter than in summer. Author concludes that in addition to direct action of temp. on bacteria, also indirect action, owing to its effect on organisms which feed on bacteria. Light also affects bacterial development, but cannot be major factor in variations in no.—*W.P.R.*

Effect of Volatile Solvents on Bacterial Numbers in Sewage. H. HEUKELEKIAN AND H. B. SCHULHOFF. Sew. Wks. Eng. **11:** 592 ('40). Expts. made to find effect of benzene, carbon tetrachloride, petrol, and kerosene on no. of bacteria in sewage. Solvents added in concns. of 0.1, 0.5, and 1.0 ml. per l. of sewage in stoppered bottles; samples taken at intervals and plate counts made after incubation for 7 days at 20°C. Graphs given showing counts, compared with counts in control samples without solvents. Benzene in concns. of 0.1- and 0.5-ml. per l. caused slight increase in no. of bacteria after 24 hr.; in concns. of 1.0 ml. per l. inhibitory effect observed even with short periods of contact. Carbon tetrachloride even at highest concn. used had only slight inhibitory effect after 3½ hr., but after 24 hr. considerable reduction in bacteria noted. Petrol and kerosene even in highest concns. used not as toxic as benzene or carbon tetrachloride. When solvents discharged to sewer, toxic effect would not be expected to be as high as in stoppered bottles; expts. made in open vessels, using 1 ml. of solvent per l. of sewage, to find effect on no. of bacteria when solvent allowed to volatilize; even with 1 ml. of solvent per l. of sewage, no appreciable effect. Increase in bacterial no. with long periods of contact and low concns. of solvents attributed to more rapid destructive action of solvents on protozoa which feed on bacteria. Doubtful whether such large concns. of these solvents as were used in expts. frequently found in sewage. *Discussion.* W. RUDOLFS: Large quants. of inflammable solvents in sewage more likely to cause trouble by explosions than by toxic effect on bacteria. Non-inflammable solvents may cause separation of grease which may accumulate on surface of settling tanks, and may interfere with filtration. Small quants. of mineral oils interfere with biological activities, before toxic concns. reached, by forming film on sludge particles, floc, stones, and sand, thus preventing penetration of oxygen.—*W.P.R.*

Factors Controlling the Germicidal Activity of Oligodynamic Silver. R. L. TRACY. J. Bact. **41:** 33 ('41). In expts.

made to det. factors which affect germicidal activity of silver, 5 sources used: "activated" silver metal, silver chloride, silver carbonate, silver sulfate and silver nitrate. Activated silver prepd. by impregnating carbon blocks with finely divided silver and oxygen. Concn. of silver in test substrates detd. colorimetrically with *p*-dimethyl-aminobenzalrhodanine. Found that min. lethal concn. of silver ions dependent upon cell pop. and concn. of org. matter. About 100 times more silver required to kill 10^6 cells of *Esch. coli* in nutrient broth than in distd. water. In org. solns. more silver ions required to sterilize given unit of bacterial pop. when concn. of cells greater than 10^7 per ml., than when below 10^6 per ml. Concns. of 100–500 γ of silver per l. sufficient to kill *Esch. coli* in 1 hr. when 10^2–10^5 cells per ml. used in aq. substrates. Germicidal activity of silver independent of source when equal concns. of silver used, provided ionic dissociation occurred readily. Increased temp. decreased lethal concns. of silver for *Esch. coli* in aq. or org. substrates. At 25°C., max. germicidal activity occurred when pH value between 7 and 8. Tests with different strains of "coli-aerogenes-proteus" group, typhoid-paratyphoid-dysentery group, and *Staphylococcus aureus* indicated that difference in species among non-sporulating bacteria had little influence on germicidal action of silver.—*W.P.R.*

Research and Control. Norman J. Howard. Can. Engr.—Wtr. & Sew. **79:** 11:20 (Nov. '41). (For previous article of series *see* Jour. A.W.W.A. **33:** 1849 ('41).) Discussion of stds. of water qual., deterioration of qual. in distr. systems and related subjects. Suggested that std. sample of U.S. Treas. Std. be increased from 10 to 100 ml. In Toronto, 100-ml. portions examd. for 20 yr. or more. In view of fact that both *Esch. coli* and *Aer. aerogenes* may be derived from sewage, possibly better to exam. large no. of samples without attempting classification of types of bacteria causing fermentation than to exam. smaller no. and definitely classify types of organisms present. Hamilton, Shanghai, China, in investigating poln. of Whangpoo R., found no. of *Esch. coli communis* in feces to be remarkably constant throughout yr. and to be lower in summer. On other hand, Wells in America found that no. of *Esch. coli* in feces increased tremendously as temp. (air) increased and reached max. in Aug. Incidence of *Esch. coli* in water related to seasonal variation in intestine, i.e., is greater during summer mo. Also, most cases of deterioration of qual. in distr. systems occur in summer mo. when raw water most pold. and water temp. highest. If water adequately treated, no reason to believe that deterioration of qual. in distr. systems of great san. signif. Coincidental occurrence of intestinal disturbances due to other causes might, however, cause very embarrassing situation. Disinfection with chlorine will not ensure maint. of uniform qual. in remote parts of system unless considerable excess of chlorine maintd. Chloramine appears only soln. of problem and such treatment may become increasingly necessary if water qual. stds. made more stringent. Prevention of secondary contamn. in open service reservoirs important. Bird and fish life and surface drainage, e.g., following heavy rain, most probable causes of such contamn. In England, gulls found to be common cause of poln. of open reservoirs. Adams reported isolation of *Eberthella typhosa* from gull droppings and Houston found such droppings to contain millions of coliform organisms per g. Of interest to note, however, that gulls caught at sea failed to show presence of fecal bacteria. Similarly, fish, oysters, etc., from unpold. water found to be free from coliform bacteria, but specimens from pold. water contained excremental bacteria. Houston concluded from expts. with goldfish that presence of fish in water not likely to create or foster serious or continued infection with coliform bacteria.—*R. E. Thompson.*

The Mechanism of the Disinfectant Action of Phenol on *Escherichia coli*. A. D. Hershey. (*Published in abstract only.*) J. Bact. **41:** 35 (Jan. '41). Method developed for measurement of sublethal injury to individual bacterial cells,

based on hypothesis that cells grow at constant rate to constant max. size. Involves measurement of latent period in multiplication of individual cells, as deduced from time required to develop turbidity in single-cell cultures obtained by dilution. Procedure yielded unexpected results in study of phenol effects on *Esch. coli*. When cells exposed to continuous phenolic action, degree of injury sustained per unit time exhibited max., not in first, but in later time interval. Since this result seemingly incompatible with concept of "logarithmic order of death," new studies of kinetics of disinfection undertaken. Results obtained so far by means of viable count in accord with observations on sublethal injury. In presence of dilute phenol, "time-survivor" curve decidedly not semi-logarithmic, but suggests death may be regarded as a critical point in reactions [enzyme inactivation?] involved in cell injury. Expts. incomplete, but indicate need for critical re-exam. of question of "order of death," particularly in view of difficulties encountered in attempts to explain classical observations. [Could not this phenomenon obtain with use of chlorine?]—*Ralph E. Noble.*

The Value of Citrate-Utilization as a Means for Differentiating Between the Genera *Escherichia* and *Aerobacter*. C. N. Stark and William R. Straughn Jr. (*Published in abstract only.*) J. Bact. **41:** 88 (Jan. '41). Of 170 citrate-pos. cultures isolated from human, bovine and equine feces, 52 appeared to belong to genus *Escherichia*, on basis of methyl red and Voges-Proskauer tests. Analyses made of gas ratios (CO_2/H_2) of these citrate-pos. types. Methyl red media and essentially methods and apparatus employed by Rogers and Clark ('14–'15) used. Gas-ratio values ranged from 0.97 to 1.17, avg. being approx. 1.06, similar to that reported by Rogers, et al. ('14) for low-ratio group (approx. 1-1). Believed that utilization of citrate as sole source of carbon unreliable and unjustifiable characteristic for differentiating between genera *Esch.* and *Aer.* Validity of methyl red test, Voges-Proskauer reaction and gas ratio, as means for differentiating between these, confirmed.—*Ralph E. Noble.*

A Comparison of Presumptive Tests for Coliform Bacteria in Sea Water and Shellfish. Leslie A. Sandholzer. (*Published in abstract only.*) J. Bact. **43:** 48 (Jan. '42). Comparison made of std. lactose, formate ricinoleate and Eijkman media on 100 homologous samples of sea water, oyster meats and oyster liquors. Partial confirmation of pos. presumptives accomplished with B.G.B. and E.M.B. Confirmation completed for each test. From results obtained, M.P.N. of coliform bacteria per ml. of original sample computed and data evaluated statistically. In case of sea water, no signif. difference between the 3 presumptive media, but confirmation on E.M.B. yielded consistently higher M.P.N. values than identical tests partially confirmed in B.G.B. When oyster meats similarly tested, no valid differences in M.P.N. values found between the 3 media when partially confirmed in B.G.B. Partial confirmation on E.M.B. yielded no differences between lactose and formate or lactose and Eijkman, but formate showed signif. higher M.P.N. values than latter. Same also held for oyster liquors, except both lactose and formate yielded higher M.P.N. values than Eijkman when partial confirmation made on E.M.B. Both oyster meats and liquors showed greater M.P.N. values when confirmed with B.G.B. Mean values for oyster meats and liquors consistently greater than those for sea water regardless of presumptive or confirmation medium used.—*Ralph E. Noble.*

An Accelerated Method for the Determination of Intestinal Coli by Means of Membrane Filters. A. N. Krylova. Lab. Prakt. (U.S.S.R.) **15:** 12: 8 ('40). Use of membrane filters for determination of *Esch. coli* decreases time of analysis to 9 hr. Method compared with coliform titer determination and with Marman method. Coliform index obtained by standard method usually lower than no. of *Esch. coli* colonies obtained from inoculation according to Marman and on membrane filters.—*C.A.*

The Determination of Coliform Organisms With Violet Red Bile Agar. C. O. Hostettler. Ohio Conf. W. Purif. 20th Ann. Rept. ('40). p. 56. Applicability of "Bacto Violet Red Bile Agar," as used in milk analysis, to water exam. investigated. Composition of medium, in grams per liter, is as follows: peptone 10, lactose 10, bile salts 1, yeast extract 5, agar 15, neutral red 0.05, crystal violet 0.004. Special bile salt used which is precipitated by acids produced during fermentation of lactose. Recommended procedure to use 15–20 ml. medium for each 90-mm. petri dish, incubate at 37°C. for 18–20 hr., and examine by transmitted light. Organisms of coliform group form purplish red sub-surface colonies, 1–2 mm. in diam., surrounded by reddish zone of precipitated bile. Small red colonies, less than 0.5 mm. in diam. and without halo, are not, as a rule, members of coliform group. Surface colonies of coliform group, which may be avoided by double plating, may be red or pinkish white in color. Incubation for longer than 24 hr. permits development of other organisms, confusing count. No. of colonies per plate should not exceed 150. In Akron expts. 10-ml. portions of river, raw and applied waters and 50 ml. of filtered and chlorinated waters placed in petri dishes and like amounts of double strength medium added. In parallel plantings of 492 samples in this manner and in standard lactose broth, both positive in 210 cases, both negative in 196, agar was positive and broth negative in 67, and agar negative and broth positive in 19. Total no. positive by plate count 277 and by standard method 229. In addition to being more efficient, violet red bile agar gives coliform density in actual counts instead of no. based on theory of probability and results are obtained within 24 hr.—*R. E. Thompson.*

The Growth of Coliform Bacilli in Distilled Water. Joseph W. Bigger and J. Havelock Nelson. J. Path. Bact. 53: 189 ('41). Filtration of natural waters, which in natural state not capable of supporting growth of *Esch. coli*, through Chamberland filters may render them growth-supporting. Filter probably removes inhibitory substances and permits use of nutritive substances in water. Distd. water can be rendered growth supporting by contact with rubber tubing. Talc used as surface dressing responsible for this effect. Neither talc nor rubber is source of nutrients. Expts. indicate that carbon dioxide, ammonia and perhaps other gases in air serve as nutrient materials. Role of talc obscure; probably acts as catalyst, as it must remain present throughout period of growth. Under these conditions, bacilli probably obtain energy from oxidation of ammonia. Growth does not occur in water-talc prepns. *in vacuo*, nor in atmospheres of oxygen, hydrogen or nitrogen. Fails to occur if air treated with soda lime, sodium hydroxide or sulfuric acid. Distd. water rendered growth-supporting by 20 out of 75 other insoluble inorg. substances substituted for talc. This power of *Esch. coli* to utilize simple chem. substances as nutrients places it in facultatively autotrophic group.—*C.A.*

Further Observations on the Origin of *Esch. coli* in the Human Intestine Murray P. Horwood and Willard D. Nalchajian. (*Published in abstract only.*) J. Bact. **43:** 21 (Jan. '42). Specimens of intestinal contents obtained aseptically from 4 points in intestinal tract of 16 persons, 55 yr. old or over. None suffered from primary intestinal disease. All, except 1, autopsied within 20 hr. after death. Specimens obtained from 3 points in small intestine (s.i.) and from point midway across transverse colon. Specimens planted in duplicate tubes of lactose broth and B.G.B. 2%. Pos. tubes transferred to E.M.B. plates, incubated and observed for *Esch. coli* and *Aer. aerogenes* colonies. Typicals transferred to agar slants and studied by usual methods and differential media. *Aer. aerogenes* isolated from 12 of 16 cases, readily from any portion of s.i. and median point of transverse colon, but yield materially greater on proximal side of caecum. Conversely, greater distance distally from caecum, greater probability of isolating *Esch. coli* than *Aer. aerogenes.* If s.i. contains large

amts. fresh bile, *Aer. aerogenes* tends to be inhibited and isolation becomes difficult (2 cases). Where starvation and emaciation preceded death, *Aer. aerogenes* less common than *Esch. coli* in s.i. In well nourished cases, *Aer. aerogenes* more common in s.i. Even so, transformation to *Esch. coli* as predominant strain in large intestine (l.i.) occurs. Sooner fecal specimens obtained after death in well nourished cases, greater was probability that *Aer. aerogenes* would predominate in s.i. and *Esch. coli* in l.i. In view of close relationship between them, would seem that, in normal human intestine, *Esch. coli* in feces has origin primarily as *Aer. aerogenes* in s.i.—*Ralph E. Noble.*

Anaerogenic Derivatives of Papillae-Forming Strains of *Escherichia coli mutabile*. Mary Louise Robbins and Leland W. Parr. (*Published in abstract only.*) J. Bact. **43:** 19 (Jan. '42). 59 strains of papillate *Esch. coli mutabile* subjected to "multiple subculture" technique. Broth cultures of papillae showed prompt fermentation of lactose in each strain. In 2 instances, upon subculturing, anaerogenic strains derived, breeding true throughout all succeeding manipulations. All other strains tested, including descendants of 2 strains above, continued to produce acid and gas consistently. Both anaerogenic cultures tested in variety of other carbohydrates. In no instance was gas produced. Agglutination tests made. In each case, antiserum was one produced against original strain from which anaerogenic form derived. Titer of each anaerogenic derivative as high as that of corresponding unchanged descendant. Occurrence of such anaerogenic strains has important taxonomic implications. Although presenting marked difference in characteristics often existing between 2 entirely distinct species, anaerogenic strain and its aerogenic relative cannot be classified separately because their descent from common ancestor definitely demonstrated. Anaerogenic phenomenon may also be significant in sanitation. Water sample could contain only anaerogenic forms thereby passing as uncontamd. in routine test. In view of anaerogenic coliform association with pathological conditions, such failure might be significant.—*Ralph E. Noble.*

The Sanitary Significance of Pectin-Fermenting Coliform Bacteria in Water. D. B. McFadden, R. H. Weaver and M. Scherago. (*Published in abstract only.*) J. Bact. **43:** 103 (Jan. '42). Existence of pectin-fermenting (p-f.) coliform bacteria in feces of man and animals in water investigated. P-f. ability indicated by production of acid reaction in synthetic medium to which alc.-sterilized pectin added aseptically. No visible gas production occurred.

COLIFORM STRAINS	FROM FECES OF	STRAINS FERMENTING PECTIN
507	56 persons	0
68	3 horses	0
118	6 fowls	0
92	7 cows	3 (same cow)
44	3 mules	7 (same mule)
115	7 dogs	38 (4 dogs)
259	from water	71

Four p-f. strains have characteristics of *Esch. coli*, 28 those of *Aer. aerogenes* and 32 those of intermediates. Some may belong in genus *Erwinia* or among non-pigmented *Serratia*. Present information not adequate to make such differentiation. P-f. ability probably will not differentiate *Erwinia* from *Esch.* As relatively more p-f. coliform bacteria found in water than in feces of animals, some, at least, probably not of fecal origin.—*Ralph E. Noble.*

Coli-Aerogenes Bacteria in Soil. Nathan Frank and C. E. Skinner. (*Published in abstract only.*) J. Bact. **42:** 143 (July '41). 356 strains of coli-aerogenes organisms isolated from soil following preliminary enrichment in duplicate in brilliant green lactose bile. Soils were virgin or field soils unmanured within past 10 yr. Not more than 4 strains isolated from any 1 sample. All colonies picked at random and repeatedly replated for purif. Voges-Proskauer, methyl red, citrate, and

indole tests showed: *Escherichia*, indole-pos. 19.66%, neg. 1.4%; intermediates, indole-pos. 3.93%, neg. 30.34%; *Aerobacter*, indole-pos. 11.52%, neg. 33.15%. All but possibly 1 gave pos. V.-P. test when methyl red was neg., or vice versa. High incidence of coli and intermediates and necessity for repeated replating to purify cultures stressed.—*Ralph E. Noble.*

Some Characteristics of a Coli-Like Organism Isolated From Chlorinated Water. J. M. Coblentz and Max Levine. (*Published in abstract only.*) J. Bact. **41:** 89 (Jan. '41). Organism has been isolated from surface water supply that had been treated with 0.6 ppm. chlorine (Cl_2) plus 0.6 ppm. ammonium sulfate. Contact period had been 1½ hr. at 0°C. with 0.45 ppm. residual Cl_2. Characteristics of organisms conformed to those of coliform group, as stipulated in *Standard Methods*. Gram-neg., non-spore-forming rod, fermenting lactose with gas production and grew aerobically. Culture much more resistant to Cl_2 than *Esch. coli*. Spores not demonstrated, but culture had many characteristics of members of genus *Aerobacillus*. Although more resistant to heat than *Esch. coli*, culture not highly resistant, being killed in 10 min. at 80°C. Organism did not grow well on nutrient agar, but grew luxuriantly in presence of carbohydrates. Produced very small colonies, having marked metallic sheen on eosin-methylene blue agar. No growth occurred on MacConkey's agar nor in tryptose-lauryl sulfate medium of Mallman. On glucose agar, large, slimy, almost-transparent colonies (1 cm. or more in diam.) formed, but capsules not demonstrated.—*Ralph E. Noble.*

Iron Bacteria: Classification, Identification and Corrective Measures. Anon. Pub. Wks. **70:** 22 (Oct. '39). When iron present in water (about 2 ppm.), iron bacteria may grow, causing serious trouble. Iron-forming bacteria classified according to physical forms into two groups: higher bacteria such as *Crenothrix*, generally recognized by threadlike form; and lower bacteria such as *Siderocapsa*, occur in spherical, spiral, or rodshaped forms. Dosage of 0.5 ppm. of chlorine considered sufficient to kill iron-bacteria growths, with heavier applications and flushing where growths accumulated, as in wells, reservoirs, and pipes. For sulfur bacteria, 1.0 ppm. activated carbon found effective.—*P.H.E.A.*

Bacteriophages in Soil. C. L. Pasricha and B. M. Paul. Indian Med. Gaz. **76:** 416 (July '41). During course of certain expts. designed to demonstrate antagonistic bacteria for intestinal pathogenic bacteria of man, interesting observation made that many samples of garden and field soil contain bacteriophages active against these organisms. 1 in 100 suspension in saline of soil when added in 1-ml. amts. to melted agar contg. thick suspension of one of test bacteria and poured, after incubation, showed no. of bacteriophage colonies. *Eberthella typhosa*, *B. flexneri*, *B. shigae* and *Vibrio cholerae* used as tests organisms, and from 12 to 16 samples of soils examd. bacteriophages active against some or all four test organisms isolated. In some plates as many as 120 bacteriophage colonies present. Most frequently occurring bacteriophages were dysenteryphages and next in order typhoidphages and choleraphages. These bacteriophages present in samples of soil taken at different levels (down to 3′) below surface. Findings demonstrate how widely bacteriophages distributed in nature.—*P.H.E.A.*

Ferrobacteria of Caucasian Mineral Springs and Their Rôle in the Formation of Ferrous Deposits. O. Y. Volkova. Mikrobiol. (U.S.S.R.) **8:** 863 ('39). (*In English*, p. 886) Typical iron bacteria, chiefly *Gallionella*, occur in springs of Zheleznovodsk and Pyatigorsk at temp. of 27–32°, but not in springs with temps. of 40–55°. Bacteria occur near outlets, where supply of oxygen highest. Not affected by seasonal changes, high content of mineral matter, low content of ferrous iron (3–4 g./l.), content of carbon dioxide in water, by light or darkness, nor by swiftness of flow. Optimum pH value 7–7.6. Presence of iron bacteria influences pptn. of iron. In bottling

waters, they are filtered in atmosphere of carbon dioxide, since satn. with carbon dioxide helps to keep iron dissolved in bottled water.—*W.P.R.*

A Spore-Forming Lactose-Fermenting Organism From the Lexington Water Supply. David B. McFadden. (*Published in abstract only.*) J. Bact. **40:** 464 (Sept. '40). Spore-forming, lactose-fermenting organism isolated from Lexington, Ky., water supply. Organism considered responsible for frequent pos. and doubtful presumptive tests from supply. When first isolated, apparently micro-aerophilic since it grew only as sub-surface colonies in poured agar plates. Later adapted itself to grow moderately well under aerobic conditions. Most closely resembles *Cl. tertium* and *B. aerosporus*. Differs from former in that it liquefies gelatin, ferments inulin, and does not have strictly terminal spores. Differs from latter in failure to grow on Endo or eosin methylene blue agar plates, and to digest or "black rot" carrots. Also does not produce central spores.—*Ralph E. Noble.*

Control of Drinking Water in Cochin-China—Study of Bacteriological Technique. J. Guillerm, C. Lataste and A. Vialard-Goudou. Arch. Inst. Pasteur Indochine. ('38). p. 475. In studying local conditions of fecal contamn., certain modifications of classical methods regarding estn. of *Esch. coli* in water suggested: (1) use of 0.8% C_6H_5OH, instead of 1% prepn. of titrated soln. of phenic acid; (2) quick identification of cultivated germs in pos. cases without indole and hydrocarbonated fermentation on $C_{12}H_{22}O_{11}$ medium (merely qual. estn. of indole interferes with correct interpretation of result); (3) search of enterococcus in pos. cases by culture on 1.8% phenic medium; (4) identification of *B. perfringens* and other anaerobic spores of intestines by culture in glucose medium; (5) reduction of sulfite in presence of Fe and formation of black colonies.—*C.A.*

CHEMISTRY

Properties of Ordinary Water-Substance. N. Ernest Dorsey. *Am. Chem. Soc., Monograph No. 81.* Reinhold Publishing Corp., New York ('40). pp. xxiv + 673; $15. Book is result of project begun by com. of Natl. Bureau of Stds., chairman being late Dr. E. W. Washburn, chief chemist. Purpose of project to compile all material likely to be of interest to anyone studying properties of water, exclusive of several isotopic waters such as deuterium oxide (heavy water). Com. plans included "(a) assembling from *International Critical Tables* all data pertaining to properties of ordinary water-substance in all its phases, (b) revision and extension of those data in light of more recent work, (c) inclusion of types of data that had been omitted from Tables, either through oversight or because of nature of plan adopted, and (d) arrangement of whole to facilitate its use." Chem. properties and reactions not considered.

Description of arrangement of tables (289), of method used for literature refs. (more than 2,170), and of symbols, units and equivalents (tabulated) given in introduction. Book divided into 5 sections: (I) Synthesis and Dissociation; (II) Single-Phase Systems; (III) Multi-Phase Systems; (IV) Phase Transition; and (V) Miscellanea. Largest section, on single-phase systems, subdivided into 3 parts: water vapor (124 pp.), water (235 pp.) and ice (105 pp.). In all fields but those covered by *International Critical Tables* prior to Jan. 1, '23, compiler himself searched journals prior to June 30, '37. Tables complete in themselves, each contg. information concerning units used, deg. of precision and sources from which data derived. Method of computation used in obtaining tables presented and exptl. methods described in detail. Very complete subject index with many cross-refs. enhances value of monograph. Many topics indexed under several entries to aid in finding desired information.

Contrary to most texts presenting detailed scientific data, presentation is excellent with much fascinating descriptive and qualitative information. Would be impossible to list all types of data presented under topics varying from acoustic data for ice to dielectric strength of water vapor. 25 pp. devoted to forms and formation of ice; 56 pp., with 19 tables, devoted to pressure-volume-temp. associations for water and 27 pp., with 15 tables, cover pressure-volume-temp. association for satd. water and steam. Vaporization and condensation discussed in 18 pp., with 7 tables. Other topics of general interest include following: soly., rate of soln. and diffusion of gases in water; freezing and melting; reflection of water, ice and snow; and luminescence of water vapor, water, and ice. 14 refs. given in interesting discussion on color of water and of sea, and 14 listed on prepn. of dust-free water.

Much of the data could not be obtained from readily available Am. journals. For instance, of 6 refs. on elec. conductivity of ice, 4 from foreign journals, and of 25 refs. on thermal conductivity of ice and snow, all of foreign origin and only one reprinted in Am. journal. Several others serve as basis for *International Critical Tables*.

[Obviously book represents years of painstaking work for benefit of everyone interested in properties of water. Every ref. library should include this monograph. Its value as vast store of selected information exceeded only by completeness of listed sources from which data selected.]—*T. E. Larson.*

Biochemical Studies on the Purification Mechanism of Activated Sludge. MASAZO WATANABE. Mitt. Med. Akad. Kioto. (Jap.) **30:** 861 ('40) (in German). *I. The Biological Action of Activated Sludge.* Ease of decompn. of carbohydrates by activated sludge (act.sl.) decreased in order: glucose, glycogen, starch, maltose, mannose, lactose, levulose, arabinose, galactose, xylose. Decompn. accelerated by continuous aeration; i.e., it increased with better development of aerobes in act.sl. Optimum pH for decompn. during aeration 7.0. Decompn. increased with increase in temp. between 10° and 37°. Decompn. of nitrogenous substances, as ovalbumin, urea and city waste water, with act.sl. estd. by detg. org. N, $KMnO_4$ consumption and B.O.D. Optimum pH generally between 6.3 and 7.3, although it varied more or less according to substances present. Influence of amt. of act.sl. on purif. effect compared at various concns. of act.sl. With ordinary city waste water, optimum concn. of act.sl. (ratio of act.sl. to waste water) about 30%; greatest decrease in org. N and B.O.D. occurred at this concn. Influence of concn. of act.sl. small with dild. waste water, but very pronounced with highly contamd. waste water. In waste water highly contamd. artificially with milk, purifying action of act.sl. increased with increasing concn. of act.sl. Properties of waste water must always be considered in estg. amt. of act.sl. to be added. Purifying action with regard to nitrogenous substances always smaller with old act.sl. than with fresh. Decompn. of olive oil with act.sl. poorest, compared with other org. substances. Optimum pH at 7.0. Decompn. more or less accelerated by aeration. Here, it is question not only of direct microbiol. action, but also, at least in part, of enzymic action of act.sl. *II. The Enzymic Action of the Activated Sludge.* Filtration of suspension of act.sl. through Berkefeld filter yielded bacterium-free fluid, contg. hydrolytic enzymes, as amylase, protease (pepsin and trypsin) and lipase. Both bacterium-free act.sl. fluid and act.sl. suspension had relatively high amylase activity; optimum pH was 6.5. Test for zymase activity of act.sl. fluid neg. Amylase in question readily adsorbed by fuller's earth or animal charcoal, but poorly adsorbed by kaolin. Soln. obtained by elution of fuller's earth or animal charcoal adsorbate with $N/15$ phosphate soln. had very high amylase activity. Protease activity relatively lower in act.sl. fluid than in act.sl. suspension. Tryptic activity always higher than peptic activity; tryptic activities of act.sl. suspension and fluid about 3.3 and 4 times higher, resp., than corresponding peptic activities. Lipase ac-

tivity always higher in act.sl. suspension than in act.sl. fluid; optimum pH 6.5. Act.sl., therefore, possesses definite enzymic activity in addn. to bacterial activity. These hydrolytic enzymes probably either come from waste water itself (plant or animal disintegration) or represent products of act.sl. bacteria. Difficult to establish true enzymic nature of act.sl. suspension which has been treated with toluene, since such treatment does not always render suspension sterile. Activity of amylase of act.sl. increased by vigorous aeration; further increased by previous addn. of starch. Enzymic activity of act.sl. probably closely related to degree of development of aerobic bacteria. Enzymic activity, together with biol. activity highly important in purif. mechanism of act.sl. *III. Adsorption by Activated Sludge.* Dried act.sl. powder adsorbs saccharides, as glucose, levulose and maltose; in dil. soln. adsorption equiv. reached within 10 min. Adsorption highest for glucose, lowest for maltose. Adsorption of act.sl. by dried act.sl. marked compared with that of above carbohydrates. Freundlich adsorption equation holds for adsorption of carbohydrates and of act.sl. by dried act.sl. Adsorbability of fat acids in aq. soln. by act.sl. decreases in order: valerianic acid, butyric acid, propionic acid, acetic acid, formic acid; i.e., their adsorbability increases with increasing mol. wt. Traube theory valid both for charcoal and for act.sl. With dried act.sl., exponent, $1/n$, of adsorption isotherm varies from 0.1756 for act.sl. to 0.8749 for levulose. Adsorption capac. of fresh raw act.sl. always smaller than that of dried act.sl. Adsorption of org. and inorg. substances on raw act.sl. proceeds according to Freundlich adsorption equation; Traube theory also holds for raw act.sl. Adsorbability of dyes on fresh act.sl. decreases in order: methylene blue B, phosphine, Auramine O, crystal violet, Benzo Brown B, Japanol Dark Green B, Silk Ponceau G, Benzopurpurin B, Rhodamine B, Congo Red. Exponent, $10n$, varies from 0.3422 for Congo Red to 0.8454 for Benzopurpurin B. No regularity found between adsorbability of dyes and their chem. constitution. When artificial adsorbents, as kaolin, animal charcoal and fuller's earth, used in presence of bacteria and protozoa, course of purif. process, studied by following $KMnO_4$ consumption, similar to that obtained with fresh raw act.sl. *IV. Polarographic Studies on the Specific Ash Constituents of Activated Sludge.* Ash of act.sl. contained Cu 4.48, Zn 1,214.64, Pb 478.000, Al 27.66, Mn 3.98 and Cd 5.56 mg. per 100 g. estd. polarographically, and Fe 6,148.24, Na 610.00, K 13.00, Mg 1,006.00, Ca 490.00, Si 19,483.00 and P 1,207.00 mg. per 100 g., as detd. by chem. methods. Sum of oxides of above elements makes up 58.5% of act.sl. ash. Act.sl. ash contained practically no Ni, Cr or Co. Trace elements probably related to activity of act.sl. and may be important for plant growth.—*C.A.*

A New Method for the Estimation of the Putrefaction Capacity of a Contaminated Water by Means of the Potassium Ferricyanide Consumption. MASAZO WATANABE. Mitt. Med. Akad. Kioto. (Jap.) **30**: 1009 ('40) (in German). Transfer 5 ml. $K_3Fe(CN)_6$ soln. (16.46 g. $K_3Fe(CN)_6$ dissolved in 1 l. water) to 500-ml. volumetric flask and fill to mark with water under examn. Pipet 20 ml. of this soln. into test tube and heat exactly 15 min. on boiling water bath. Cool, add 3 ml. I-Zn soln. (5 g. KI + 10 g. $ZnSO_4$ + 50 g. NaCl dissolved in 200 ml. water), 2 ml. AcOH soln. (3 ml. glacial AcOH in 100 ml. water) and few drops of starch soln. (1 g. starch in 100 ml. satd. NaCl soln.), and titrate mixt. with 0.005 N Na thiosulfate soln. If x = amt. of Na thiosulfate used, $K_3FE(CN)_6$ consumption in mg. per l. water can be calcd. from following equation: $0.1646 \times (2x) \times 1000/20$ = mg. $K_3Fe(CN)_6$ per l. water. $K_3Fe(CN)_6$ consumption exactly same for raw waste water and corresponding sterilized waste water. Change in $K_3Fe(CN)_6$ consumption of waste water essentially parallels bact. count. $K_3Fe(CN)_6$ consumption of river water increases with increase in its $KMnO_4$ consumption. Decrease in $K_3Fe(CN)_6$ consumption of waste water exactly proportional to its diln. $K_3Fe(CN)_6$ consumption of water which contains H_2S closely connected with its

H_2S content; it can be assumed that $K_3Fe(CN)_6$ consumption of waste water reveal its H_2S content. Greater the $K_3Fe(CN)_6$ consumption of waste water, greater is its putrefaction capac.; one $K_3Fe(CN)_6$ consumption detn. of water will, therefore, reveal its putrefaction capac. Procedure also permits orientation as to purif. effect of waste water to be purified biologically, since $K_3Fe(CN)_6$ consumption almost proportional to oxidizability of water.—*C.A.*

The Significance of the Froboese Chlorine Number in the Determination of Organic Substances. M. Hiura. Mitt. Med. Akad. Kioto. (Jap.) **28:** 724 ('40) (in German). Relation between chlorine no., as estd. by Froboese modification of procedure of El'manovich and Zaleskiĭ, and potassium permanganate demand of water contg. org. substances in concns. of 20, 50, or 100 mg./l. studied. Org. substances used: glucose, xylose, sucrose, maltose, starch, oxalic, propionic, butyric, isovaleric and benzoic acids, glycine, *d*-alanine, *d*-glutamic acid, *l*-leucine, urea, amino-acids, and proteins and their decompn. products. Chlorine no. of org. substances depends essentially on their chem. constitution. Chlorine no. of nitrogen compds. high in comparison with their permanganate demand; detn. of chlorine no. of water contamd. with proteins or their decompn. products therefore more sensitive and accurate than estn. of oxidizability by Kubel-Tiemann procedure. Both chlorine no. and consumption of potassium permanganate should be estd. in studying deg. of contamn. of water by org. substances.—*W.P.R.*

Old and New Systems for Reporting the Inorganic Constituents in Natural Waters. V. G. Anderson. Chem. Inst. J. & Proc. (Australia) **7:** 187 ('40). Outlines work on anal. of water since 1663. Modern methods of expressing results of anals. discussed. Although in some ways expression of results as hypothetical compds. undesirable, may be of value in certain cases, e.g., when detg. type of scale which water would form in boiler. Author proposes expression of each radical as percentage of chlorides present. Method particularly suitable for Australia, where most waters contain considerable amts. of chloride. By using method, similarity of many waters to one another and to sea water becomes apparent. Graphical method of expressing results, in which radicals represented on sides of parallel-sided fig. described; general characteristics of water can be seen from shape of fig.—*W.P.R.*

Irregularities in the Results of the Determination of Hardness by the Boutron and Boudet Method in Waters Containing Strontium Salts. E. Niccoli and V. Casini. Chim. Ind., Agr., Biol. (It.) **17:** 187 ('41). Gravimetric control, i.e. detn. of Mg and Ca, in waters contg. Sr salts does not correspond to hardness detns. by Boutron and Boudet method. Results obtained by this method always higher than theoretical, but not possible to calc. true coef. for correction.—*C.A.*

A Cheaper Nessler's Reagent by the Use of Mercuric Oxide. L. F. Wicks. J. Lab. Clin. Med. **27:** 118 ('41). Red mercuric oxide (analytical reagent qual.) and twice usual equivalent of potassium iodide used in prepn. of Koch-McMeekin soln. Reagent, identical in compn. with solns. prepd. by original formula or by use of mercuric iodide, obtained at less expense.—*C.A.*

A Note on the Decomposition of Nessler's Solution. W. E. James, F. A. Slesinski and H. B. Pierce. J. Lab. Clin. Med. **27:** 113 ('41). Extreme sensitivity of Nessler's reagent to fumes of acetone emphasized. Appearance of yellow ppt. in solns. stored in rubber-stoppered bottles traced to presence of rubber stoppers. They had been wiped with acetone to remove blood on rubber. —*C.A.*

Anhydrous Sodium Thiosulfate, Primary Standard. Hazel M. Tomlinson and Frank G. Ciapetta. Ind. Eng. Chem.—Anal. Ed. **13:** 539 (Aug. '41). Sodium thiosulfate pentahydrate after dehydration at 120°C. suitable for use as primary std. in iodimetry. When accuracy greater than 2 parts per thousand

not obligatory, cp. salt of commerce may not require recrystallization.—*Selma Gottlieb.*

Synthetic Resins as Exchange Adsorbents. ROBERT J. MYERS, JOHN W. EASTES AND FREDERICK J. MYERS. Ind. Eng. Chem. **33:** 697 (June '41). Discovery by Adams and Holmes in '35 that phenol-formaldehyde resins show ion-exchange properties opened new fields in chemistry of synthetic resins, and in base-exchange phenomena. Characteristics of non-resinous exchange adsorbents discussed. Resinous cation exchange adsorbents can be made advantageously with naturally occurring tannins as source of polyhydric phenolic nucleus, and condensing with formaldehyde. Introduction of strongly acidic groups, e.g., alkyl or aryl sulfonic acids, gives increased exchange capac., esp. at low pH. Anion exchange or acid-adsorbent properties can be made by condensing aromatic amines such as aniline or *m*-phenylone diamine with formaldehyde. Condensation of amine with monosaccharide yields anion exchanger renewable by alkali. Both resins may be viewed as insoluble "lattice" contg. "active spots." Research here and abroad has developed superior resins with increased mech. and chem. stability, higher exchange capac. and velocity, greater porosity and improved regenerability. The Resinous Products & Chemical Co. has developed the Amberlite-IR resins which are homogeneous gels combining large inner surface and high reactivity with mech. strength. Now in commercial production on small scale, and are but examples in varied scheme with any desired phys. and chem. properties. Exchange reactions are typically:

$$2\,NaR + CaSO_4 \rightarrow CaR_2 + Na_2SO_4$$
$$HR + NaCl \rightarrow NaR + HCl$$
$$X + H_2SO_4 \rightarrow X \cdot H_2SO_4$$

where NaR is Na salt of cation-exchange resin, HR is H form of same resin, and X is anion-exchange (acid-adsorbent) resin. Passage of water through double system of anion and cation exchangers removes all dissolved salts, and yields effluent comparable to distd. water in qual., though silica not removed. Also, one ion can be replaced by another as desired and salts made by double decompn. To compete in water softening field, resinous exchangers must at least meet specifications now set for zeolites, other things being equal. Grain size can be controlled, as with zeolites. Resinous exchangers are considerably lighter in wt. (true density) than greensands or synthetic gel zeolites, an advantage in backwashing, though exchanger bed must have adequate freeboard to prevent mech. loss of resin. Resinous exchangers imbibe water and swell when dry product is placed in water; those showing high degree of swelling are finished wet. Capac. of wet resins on vol. basis considerably higher than that of siliceous or carbonaceous exchangers. Resinous exchangers apparently insoluble in acids, alkalis and salt solns., and in hot and cold water, and show low attrition and reaction losses. Amberlite-IR-1 had capac. of 7,200 to 16,000 grains per cu.ft. compared with value of 2,600–2,980 for greensand, 4,000–5,500 for synthetic zeolites and 5,500–7,000 for carbonaceous zeolites. Previous data of workers abroad indicate that synthetic resin exchangers well-suited for water softening applications and possess many advantages over older exchange adsorbents. Resins contg. sulfonic acid groups may be converted to hydrogen derivative by dilute acid, resulting H then being capable of replacing all cations, including Na and K, in aq. solns. undergoing treatment. Regeneration is by 1 to 2% HCl or H_2SO_4. Bicarbonates and carbonates are converted to carbonic acid removable by aeration, thus lowering total solids, alky. and hardness. Free mineral acids produced may be neutralized with alkali or preferably removed by anion-exchanger adsorbent. Exchange is stoichiometric and can be used for detn. of cations, resulting free acid being titrated with 0.1 *N* alkali. On exhaustion, titration value drops rapidly, but if original water contains both Na and Ca, resin will then act as Na exchanger, no Ca passing until Na resin exhausted. Capac. of tannin-formaldehyde resin for

Ca/H exchange was from 7,550 to 8,650 grains per cu.ft., in same general range as results on carbonaceous zeolite previously reported by Applebaum. Anion-exchanger resins probably act by adsorbing whole acid molecules, very little neutral salt cleavage occurring, though easily hydrolyzable salts of weak bases are split and resulting acid removed. Sulfate may be replaced by Cl by passing SO_4 soln. over anion-exchange resin in its hydrochloride form. Capac. varies considerably with chem. constitution, improved aromatic diamine resin and new type of anion-exchanger resin giving most encouraging results. Diamine resin showed marked dependence of exchange capac. upon developed surface, but new anion-exchange resin did not. No suitable materials available for comparison tests with resins of this type. Anion-exchange resins successfully used in tandem with H-exchangers to produce high quality "chemically distd." water on lab. scale from Philadelphia tap water. Chem. constitution as well as compn. det. capac. of resin adsorbents, though chem. compn. alone dets. for siliceous and carbonaceous exchangers. Resins exchangers feasible for softening water for industrial and domestic use and for solids reduction for industrial use. Acid in H-exchanger-treated water can be neutralized by bicarbonate in raw or Na-exchanger-treated water. Ion-exchange resins, because of chem. stability, may be used for recovering valuable electrolytes from very dilute solns., e.g., Cu from industrial effluents or mine wastes, traces of undesirable metal ions from metal salts, traces of electrolytes from solns. of non-electrolytes. Traces of acidity may be removed by simple adsorption with no neutral salt being imparted. Softening of hot water requires special resins, already developed.—*Selma Gottlieb.*

Synthetic-Resin Ion Exchangers in Water Purification. Operating Characteristics. Robert J. Myers and John W. Eastes. Ind. Eng. Chem. **33:** 1203 (Sept. '41). Operating characteristics of synthetic-resin ion exchangers studied in apparatus larger than usual lab. equip. Results showed that these resins are stable in acid, neutral or alk. solns., have high capac. and can be efficiently regenerated. For cation exchanger (Amberlite-IR-1), downward flow with 4 to 7% salt concn. best method of regeneration. Capac. remains constant after repeated partial regeneration or "bed starvation." Break-through and total capacs. independent of water hardness. High concn. of sodium ions tolerated before eff. of calcium removal impaired. Ca effectively removed in pH range of 1.8 to 9.03. When same resin regenerated with acid (4% HCl), hydrogen cycle results and resin converts bicarbonate to carbonic acid removable as CO_2 by aeration. Anion exchanger (Amberlite-IR-4) removes anions in their acid form but does not extensively remove them from solns. of neutral salts. Preferential adsorption of certain ions noted. Rates of operation and regeneration influence results in anion exchangers, slower regeneration giving better results. 2% Na_2CO_3 most practical; has extremely high adsorption capac. and high chem. eff. of regeneration.—*Selma Gottlieb.*

Water Absorption of Resins. Ernest P. Irany. Ind. Eng. Chem. **33:** 1550 (Dec. '41). Most resinous materials used in new plastic arts are water insoluble but still capable of absorbing varying amts. water upon extended immersion. Process may depend on true but limited soly. of water in resinous medium, on chem. or sorptive phenomena, or capillary action. For quant. study of water absorption, necessary to observe whole course of absorption-time functions under isothermal conditions. Homogenous resinous substances absorb water by diffusion, in good accord with theoretically deduced law. Latter specifies 2 independent material factors, P, rate of penetration or permeability, and S, satn. limit under given conditions. Both. consts. required for adequate description of material. In presence of dispersed granular or fibrous fillers, capillary action predominates. Water-attracting or binding agents, e.g., hydrophylic chem. groups on resin molecule or impurities such as soluble salts, cause deviations from fundamental régimes.—*Ralph E. Noble.*

Concentration of Dilute Solutions of Electrolytes by Base-Exchange Materials. ROY H. BREATON AND CLIFFORD C. FURNAS. Ind. Eng. Chem. **33:** 1500 (Dec. '41). Hitherto, base-exchange (b-e.) substances used to remove calcium and magnesium nuisances from potable waters and replace with sodium. Much larger field promised in recovery of chem. values. B-e. reactions between copper sulfate solns. and carbonaceous zeolite in hydrogen form studied. Particular emphasis placed on H-ion concn. Cu concns. ranged from 0.5 to 900 moles per l. and H-ion concn. from 9.5×10^{-6} to 3.5×10^{-2} mole per l. Zeolite shows buffering action at pH 1.98, with characteristics distinctly different on 2 sides of this apparent isoelectric point, indicating similarity to colloidal solns. Established that zeolite absorption capac. for Cu functioned by ratio Cu-ion to H-ion concns. alone. Rate of transfer measurements made by passing solns. through zeolite beds and taking concn. history of effluent. Transfer coefs. obtained by considering b-e. analogous to heat transfer and found independent of fluid velocity. Expts. suggest avg. coef. decreased as bed height increased, probably due to released H-ions interference with the exchange reaction over increased portion of bed. Studied feasibility of using zeolites for increasing concn. of dilute solns. of cations by regenerating bed with fairly strong sulfuric acid. Starting with 0.005 *N* $CuSO_4$, over 220-fold increases in concn. obtained. Possible applications of data given. Under ideal conditions, in zeolite system contg. 0.005 *N* H_2SO_4, 1 lb. latter would effect increase in concn. equivalent to evapg. 4,200 lb. water. Demonstrates unique possibilities in zeolites for recovering valuable cations from very dilute industrial wastes.—*Ralph E. Noble.*

Determination of Phenol in Water. K. JAEGERS. Wasser u. Abwas. (Ger.) **38:** 103 ('40). Colorimetric calibration curves prepared for detn. of phenol, *o*- and *m*-cresol, naphthol, xyenol, resorcinol and pyrocatechol by use of diazotization method with *p*-nitroaniline and Folin-Denis reagent. Reagents gave widely different results with unknown mixtures of phenols. To obtain consistent results, calibration curve for mixt. contg. 50% phenol and 50% *m*-cresol should be used.—*C.A.*

Photocolorimetric Determination of Phenol in Aqueous Solutions. M. P. BABKIN. Zavodskaya Lab. (U.S.S.R.) **9:** 1244 ('40). Two methods of detg. phenol studied: (1) Moir and Hinden method with *p*-nitroaniline, and (2) Houghton-Pelly method with nitrosodimethylaniline. Former can be used to det. concns. of 0.05–10 mg./l. and most accurate results are obtained for concns. of 0.05–2 mg./l. In latter, stable blue coloration obtained which makes it possible to det. phenol with sufficient accuracy within concns. of 0.15–10 mg./l. —*C.A.*

Liquid Film Formation. A Criticism of the Balanced-Layer Theory. THOMAS H. HAZLEHURST AND HARVEY A. NEVILLE. Ind. Eng. Chem. **33:** 1084 (Aug. '41). Authors believe balanced-layer theory to be thermodynamically unsound and supported by unsound and irreproducible data, improperly evaluated. *Reply. Ibid.* p. 1086. C. W. FOULK: Grants argument of authors with regard to dynamic *vs.* static surface tension, but otherwise defends his equip., data and evaluation of results. Considers balanced-film theory useful because it enables one to predict whether certain solns. will or will not foam, whether theory is true or not.—*Selma Gottlieb.*

The Mixed Indicator Bromocresol Green-Methyl Red for Carbonates in Water. STANCIL S. COOPER. Ind. Eng. Chem.—Anal. Ed. **13:** 466 (July '41). Mixed indicator responding visually between pH 4.60 and 5.00 made by dissolving 0.02 g. of methyl red and 0.10 g. of bromocresol green in 100 ml. of 95% alcohol. Three drops of this in 100 or 250 ml. of soln. shows max. color change over this pH range, from light pink at pH 4.6, light pink gray with cast of blue at pH 4.8, and light blue with lavender gray at pH 5.0. Final equivalence point pH definitely dependent on CO_2 content

there existing, and corresponding end-point color may be selected: $pH_{e\text{-}p.} = 4.10 + \frac{1}{2} \log \left(\frac{B D}{x} + 1\right)$; where $pH_{e\text{-}p.}$ = pH at end-point; B = vol. of mixed carbonate sample, in ml.; D = vol. of A normal acid to reach HCO_3 equivalence point; and x = addnl. ml. of same acid to reach carbonic acid equivalence point. Acid used was 0.0200 N HCl standardized against Na_2CO_3. If $pH_{e\text{-}p.}$ is less than 4.60, sample should be dild. with CO_2-free distd. water before titration, or indicator converted to pink, soln. stirred vigorously for about 30 sec., and resulting blue cast converted to pink. Mixed indicator gives good agreement with values obtained by electrometric titration with glass electrode, and is more reliable than either methyl orange or methyl orange-xylene cyanole, except in solns. in which HCO_3 developed is high. If soln. is alk. to phenolphthalein, it is titrated to colorless with acid, mixed indicator added and titration completed. If free CO_2 is present, soln. is titrated to phenolphthalein end-point with NaOH or Na_2CO_3 to det. CO_2, mixed indicator added, and total HCO_3 titrated with 0.020 N HCl. Bicarbonate originally present in sample calcd. by difference. Mixed indicator can be used in all titrations of HCO_3 with acid if $pH_{e\text{-}p.}$ now lower than 4.6; e.g., soln. developing 210 ppm. of HCO_3 has $pH_{e\text{-}p.}$ 4.5., outside range of mixed indicator. Vigorous stirring for 30 sec., however, removed enough CO_2 to allow pH to rise into indicator range. Mixed indicator has not been applied to more concd. solns. but should work if CO_2 removed by agitating soln. until one or two drops of acid discharge blue developing on stirring.—*Selma Gottlieb.*

A Rapid Procedure for Determination of Carbonate. A. C. Kuyper and Lois M. Jones. Ind. Eng. Chem.—Anal. Ed. **13:** 801 (Nov. '41). Total carbon dioxide quantitatively pptd. as strontium carbonate and soln. adjusted to neutral with phenolphthalein. Known amt. acid added to liberate CO_2. Latter then aerated from soln. and excess acid titrated with alkali. If organic acid or bases present, are wholly or partially neutralized in prelim. pH adjustment; after adding acid, brought back to same state of neutralization. Phosphate pptd. as strontium phosphate and, after adding acid, re-pptd. in back-titration. Iron pptd. as its oxide and titrated back to same. When present in small amts., ammonia does not interfere; in large amts., does, with phenophthalein end-point. Magnesium pptd. as hydroxide when soln. first made alk. and dissolves slowly when neutralized. Interferes to extent not dissolved during this neutralization. This procedure faster and of more general application than limited one of simply adding acid to sample, removing CO_2 by boiling and titrating excess acid.—*Ralph E. Noble.*

Determination of Soluble Silica in Water. H. Lewis Kahler. Ind. Eng. Chem.—Anal. Ed. **13:** 536 (Aug. '41). Yellow silicomolybdate complex, formed by interaction of soluble silica and ammonium molybdate in acid soln., reduced with Na_2SO_3 to molybdenum blue, and interference by tannins, alky., phosphate, iron and other ions eliminated. Color, temp. and color progression offer no practical interference. Method requires 4 min. on 10-ml. sample, using photometer, and gives accuracy comparable to gravimetric methods. *Procedure:* To 10 ml. sample, add 5 ml. of HCl reagent (20 ml. of 1.19 sp.gr. per l.) and 5 ml. of ammonium molybdate reagent (102 g. of ammonium molybdate, contg. 81% MoO_3, per l.). Allow to stand approx. 1 min., reduce with Na_2SO_3 soln. (170 g. of 97% anhydrous Na_2SO_3 per l.). Read color in photometer, adjusting instrument to zero reference with 10-ml. sample, treated with acid and Na_2SO_3 and 5 ml. of distd. water. With quant. of HCl used, pH is 2.4 to 2.7, found to be optimum. Temp. of sample and reagents should be maintd. within ±5° of soln. temp. at time of standardization. Range of method is 0.1 to 50 ppm. of silica. Phosphate up to 150 ppm. does not interfere. Alky. up to 350 ppm. can be tolerated; boiler waters more alk. than this should be dild. Yellow color stable for 5 to 30 min.; color progression of blue reduction color easily controlled.—*Selma Gottlieb.*

Adsorption of Soluble Silica From Water. L. D. Betz, C. A. Noll and J. J. Maguire. Ind. Eng. Chem. **33:** 814 (June '41). Further studies on Remosil, specially prepd. magnesium oxide for removal of soluble silica from water with actual decrease in solids content of effluent. Previous findings that removal is due to adsorption rather than stoichiometric chem. reaction confirmed. Retention time of 15 min. sufficient under most circumstances, though longer retention increases percentage of silica removed. As is common with adsorption reactions, wt. of silica removed per part of MgO lower for higher MgO dosages and lower silica in water. Silica is at min. at pH 10.1 though it changes little from pH 9.5 to 10.6. As residual silica in treated water decreases, control of pH becomes less important. Where hot-process phosphate softening used, lab. tests indicate that MgO and NaOH should be added for silica removal, followed by filtration or sedimentation and phosphate treatment to avoid adsorption of phosphate by Mg ppts., though simultaneous treatment might be possible in field. Findings of Behrman and Gustafson, that MgO to be effective must be formed *in situ* in water to be treated, though dolomitic lime can be used under certain special conditions, verified. Additional Ca introduced may, however, cause considerable difficulty. Sludge recirculation increases amt. of silica removed per part of MgO. Data shown for plant scale operation in conjunction with hot lime-soda softening, indicating better silica removal on plant than on lab. scale.—*Selma Gottlieb.*

The Determination of Small Amounts of Copper in Water and Sewage. C. R. Hoover, J. W. Masselli and R. H. Coe. (*Published in abstract only.*) Sew. Wks. Eng. **13:** 37 (Jan. '42). Interest in effect of Cu in water and sewage due to increased use of Cu in pipe, possible changes in Federal stds. for drinking water, and large vol. of Cu-contg. wastes discharged to streams, has increased importance of detg. small amts. Several methods studied. In case of sewages and sludges, prepg. sample generally more difficult than actual quant. est. Prepn. by pptn. and extraction, Kjeldahl digestion, conventional ashing and nitric acid extraction compared. First method apparently most accurate but third one, under controlled conditions, may be made satisfactory routine. Quant. detn. by std. carbamate method compared with other colorimetric methods, visually and photoelectrically. Visual sensitivity appears greater unless deep layers of soln. used. Stability of unknowns and stds. to light apparently important.—*Ralph E. Noble.*

A Rapid Method for the Microanalysis of Lead. Lawrence T. Fairhall and Robert G. Keenan. J. Am. Chem. Soc. **63:** 3076 (Nov. '41). Permits objective separation and precise evaluation of minute amts. in drinking water and urine without ashing. 5 or 6 l. water may be extracted in 1-l. portions with 100-mg./l. chloroform soln. of dithizone. Wash extract at least 3 times with distd. water. Remove lead from chloroform layer with 10-ml. 2% nitric acid, transfer to 25-ml. Erlenmeyer flask, neutralize, reacidify with acetic acid, ppt. as chromate, boil, filter through small filter, wash, dissolve in few drops dil. hydrochloric acid and wash into 5-ml. glass stoppered flask, add potassium iodide and titrate with 0.002 *N* sodium thiosulfate soln. using microburet following addn. of 1 or 2 drops carbon disulfide to indicate end-point.—*Ralph E. Noble.*

Colorimetric Determination of Lead by Diphenyl Carbazide. T. V. Letonoff. Ind. Eng. Chem.—Anal. Ed. **13:** 631 (Sept. '41). Addnl. experience with detn. of Pb by method of Letonoff and Reinhold has revealed several points in procedure where difficulties may be encountered, and where certain modifications, although minor, may permit more accurate results to be obtained. These are elaborated.—*Selma Gottlieb.*

Photoelectric Colorimetric Technique for the Dithizone System. F. L. Kozelka and E. F. Kluchesky. Ind. Eng. Chem.—Anal. Ed. **13:** 484 (July '41). Technique described, applicable to photoelec. colorimeters for detn. of

one component in two-component system. Especially adaptable to dithizone system since it eliminates necessity of removing excess dithizone and simplifies procedure for routine anal. Recoveries of ±1 microgram of lead obtainable. Technique based on fact that lead dithizonate in CCl_4 shows max. absorption at 5200 Å where absorption of dithizone in CCl_4 is at min.—*Selma Gottlieb.*

Separation of Bismuth From Lead With Ammonium Formate. Silve Kallman. Ind. Eng. Chem.—Anal. Ed. **13:** 897 (Dec. '41). Suited for both quant. separation and detn. of Bi and Pb and for quant. separation of small amts. Bi from large amts. Pb. Nitric acid soln. of Bi and Pb neutralized with ammonia and ammonium carbonate. Ammonium formate added and ppt. of basic bismuth formate filtered, washed with hot water, re-pptd., then ignited to the oxide. Ppt. can also be dissolved in hydrochloric acid and Bi detd. as oxychloride. If bismuth formate ppt. very small, can be dissolved in dil. sulfuric acid and Bi detd. colorimetrically with potassium iodide. Pb pptd. in filtrate of the bismuth formate as chromate with potassium or ammonium dichromate.—*Ralph E. Noble.*

Colorimetric Determination of Iron With Kojic Acid. M. L. Moss with M. G. Mellon. Ind. Eng. Chem.—Anal. Ed. **13:** 612 (Sept. '41). Oxidize iron in properly prepd. sample, contg. 1 mg. of Fe or less, by boiling with a little nitric acid, persulfate or hydrogen peroxide. Dilute with iron-free water and add 1 g. of ammonium acetate, filter if not clear, transfer to 100 ml. flask, add 10 ml. of 0.1% kojic acid soln., dil. to mark and mix well. Color may be detd. by usual methods; stds. for visual comparison prepd. with same acid concn. as sample may be kept one week. Aluminum, citrate, oxalate or pyrophosphate interfere. Color less intense than with thiocyanate or *o*-phenanthroline and permits detn. without dilution on samples too high in Fe for direct detn. with thiocyanate or *o*-phenanthroline. F to 15 ppm. does not interfere; effect on color linear to 100 ppm. F.—*Selma Gottlieb.*

Thiocyanate Method for Iron. J. T. Woods with M. G. Mellon. Ind. Eng. Chem.—Anal. Ed. **13:** 551 (Aug. '41). Spectrophotometric study shows that in detn. of Fe with thiocyanate, following variables must be kept reasonably const.: amt. of reagent, amt. and kind of acid, use of excess oxidizing agent, time of standing, presence and amt. of certain interfering ions, and dielectric const. of solvent. Colors should be matched within 4 to 5 hr. For general work, *o*-phenanthroline probably best of reagents studied; mercaptoacetic acid recommended for total iron.—*Selma Gottlieb.*

Study of Ferric Thiocyanate Reaction. Charles A. Peters and Chester L. French. Ind. Eng. Chem.—Anal. Ed. **13:** 604 (Sept.'41). Max. color produced in solns. 0.01 *N* in acid, over limited range of iron. Increasing thiocyanate overcomes lessening of color intensity by higher concns. of HCl, decreases amt. of acid needed to develop same color intensity, and progressively increases colored substance with no indication of reaching max. Extraction of red color by ether depends on CNS/Fe ratio, and high ratio necessary for Fe extraction.—*Selma Gottlieb.*

A Simple Colorimetric Micromethod for Determining the Oxygen Content of Aqueous Solutions. R. Brinkman and A. van Schreven. Acta Brevia Neerland. Physiol., Pharmacol., Microbiol. (Neth.) **11:**77 ('41). 2,4-Diaminophenol dihydrochloride in alk. soln. oxidized by D.O. to stable blue compd. Intensity of color directly proportional to oxygen content. Take 0.2-ml. sample in syringe and transfer in 0.2-ml. glass-stoppered measuring tube contg. small bead and approx. 0.01 ml. diaminophenol reagent (200 mg. in 1 ml. 0.1 *N* hydrochloric acid, trace of sodium bisulfite to remove any red color and 25 ml. glycerol). Fill tube to mark, add 0.02 ml. of soln. of 250 mg. sodium cyanide in 25 ml. 10% sodium carbonate from fine jet introduced deeply below surface of liquid and stopper tube, thus discarding surface layer. Shaking produces blue color in 2 min. which is stable for 30 min. Meas-

ure color photometrically against std. curve obtained with known oxygen concns.—*C.A.*

Quantitative Determination of Dissolved Oxygen. PAUL F. SHARP, DAVID B. HAND AND E. S. GUTHRIE. Ind. Eng. Chem.—Anal. Ed. **13:** 593 (Sept. '41). Method depends on oxidation in special oxygen anal. tubes of reduced ascorbic acid by D.O. in presence of ascorbic acid oxidase from cucumbers, and titration of resulting ascorbic acid with 2,6-dichlorophenolindophenol. Developed for liquids contg. org. matter (esp. milk) it shows good agreement with Winkler method on water samples. One analyst can make 30 detns. in ½ day.—*Selma Gottlieb.*

Sulfamic Acid Modification of the Winkler Method for Dissolved Oxygen. STUART COHEN AND C. C. RUCHHOFT. Ind. Eng. Chem.—Anal. Ed. **13:** 622 (Sept. '41). Use of soln. of 4% sulfamic acid in 20% H_2SO_4 as preliminary treatment for removal of nitrites in D.O. detn. as satisfactory as azide modification for detn. of D.O. and B.O.D. in sewage treatment and river poln. studies. Azide and sulfamic acid are of equal value in prevention of biochem. oxidation when D.O. sample must be stored for short time. To make reagent, dissolve 4 g. of sulfamic acid in 50 ml. of distd. water and add 50 ml. of cold 40% H_2SO_4. Slight turbidity inconsequential. 1 ml. of this soln. added to 300 ml. D.O. sample bottle; will destroy 19.3 ppm. of nitrite N. Stopper bottle, shake, allow to stand for 10 min. and proceed as in azide modification. Sulfamic acid has advantage, over sodium azide, of cheapness, availability, nonpoisonous nature, stability in sulfuric soln. and formation of soluble sulfamates, though it is only ⅔ as effective by wt. as sodium azide.—*Selma Gottlieb.*

Dissolved Oxygen and B.O.D. Determinations. Their Application and Interpretation. C. C. RUCHHOFT. Sew. Wks. Jour. **13:** 542 (May '41). D.O. detn. used principally in activated-sludge plant control, B.O.D. studies, and in stream poln. work for following oxygen sag and studying re-aeration. Winkler method for D.O. considered most satisfactory, but, in variety of waters to which detn. applied, substances that interfere with method frequently encountered. Various modified procedures briefly discussed and recommended for various materials as follows:

Material	Modification
Paper-mill wastes contg. sulfites or sulfides	Alk. hypochlorite
Wastes contg. ferrous and ferric iron	Rideal Stewart with fluoride
Raw sewage	Alum flocculation with short Winkler
Activated-sludge mixed liquor	Sulfamic acid inhibiting reagent followed by Alsterberg azide
River waters and effluents	Rideal Stewart, Alsterberg azide and sulfamic acid

B.O.D. test which is direct adaptation of natural purif. reaction of pold. waters described, and precautions to be observed in carrying out test pointed out. Interpretation of results discussed, and generally accepted formulas for conversion of B.O.D. data obtained at one incubation time and temp. to other times and at different temps. presented. B.O.D. decrease in streams and so-called immediate demand discussed briefly.—*P.H.E.A.*

Chlorine and Salt Cake From Salt and Sulfur. ARTHUR W. HIXON AND ALVAN H. TENNEY. Ind. Eng. Chem. **33:** 1472 (Dec. '41). New sources needed to meet increased demand for Cl_2 and salt cake. Anhydrous reaction sulfur trioxide (SO_3) on NaCl offers possible means of producing sodium sulfate and Cl_2 simultaneously from cheap chems. (1) NaCl and gaseous SO_3 react to form addn. compds. of same. Reaction impeded by crust formation. (2) Higher addn. compds. unstable at room temp. (3) Between 225-300°C., 3 moles sodium chlorosulfonate liberate 1 mole each of Cl_2 and SO_2. (4) Solid residue of this

reaction empirically an equimolar mixt. sodium pyrosulfate and chloride, reacting above 300°C. to form sodium sulfate, Cl_2 and SO_2. Comparisons of possible process using these reactions with existing and abandoned processes for Cl_2 and salt cake made.—*Ralph E. Noble.*

to 1.0 atm. Results agreed well with values previously reported though hydrolysis consts. calculated have ½ to ¾ of Yakovkim's values. Equation given for extrapolating solubility values to over one atmosphere. (*See also following abstract.*)—*Selma Gottlieb.*

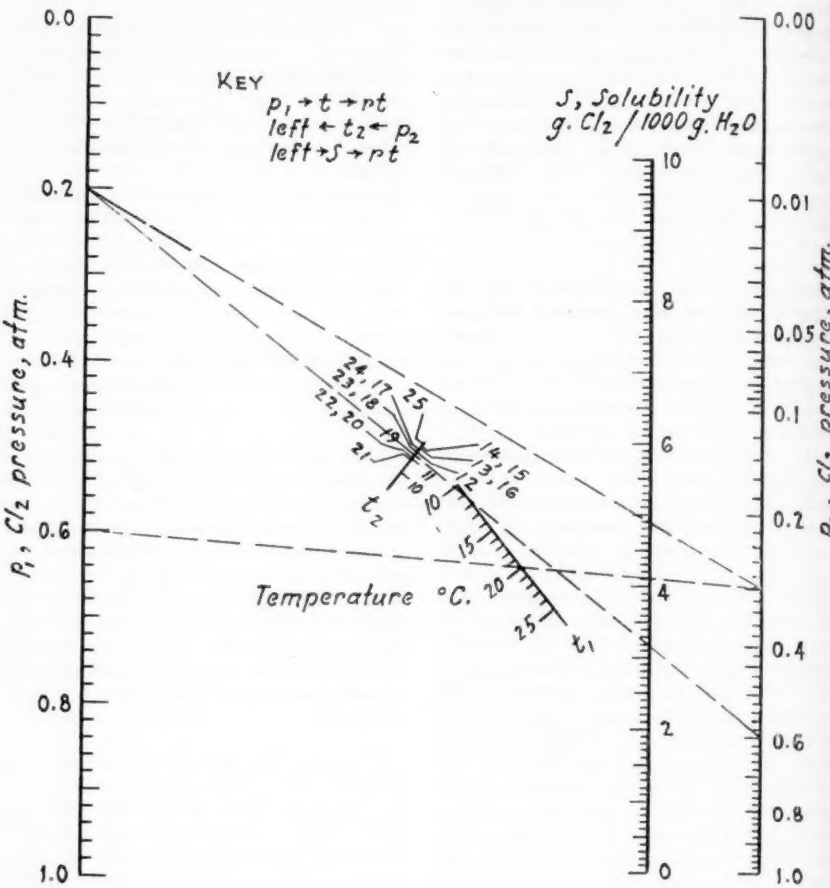


Fig. 1

Solubility of Chlorine in Water. Roy P. Whitney and J. E. Vivian, Ind. Eng. Chem. **33**: 741 (June '41). Solubility of Cl in water determined experimentally by passing various Cl-N gas mixtures through an equilibrium cell in thermostat at temp. from 10 to 25°C. with partial pressures of Cl from 0.06

Nomograph for the Solubility of Chlorine in Water. D. S. Davis. Ind. Eng. Chem. **33**: 1202 ('41). Most recent data on soly. of chlorine in water those of Whitney and Vivian [see previous abstract] who presented pressure-concn. isotherms in addn. to tabular information for ranges of 10° to 25°C., 0.06 to 1.0

atm. chlorine pressure, and 0.1 to 0.8 g. chlorine per 100 g. water. From sound theoretical considerations they derived relation between c, concn. of chlorine (in all forms) as moles per 100 g. water, and p, chlorine pressure in atm., equivalent to $c = ap + bp^{\frac{1}{2}}$, where a and b depend upon temp. Eq. and table given enable constr. of nomograph (Fig. 1) from which solys., corresponding to any temp. and pressure in ranges of data, can be read quickly and accurately. Use of chart illustrated as follows: To det. soly. of chlorine in water when pressure is 0.6 atm. and temp., 20°C., follow key, connecting 0.6 on p_1 scale with 20 on t_1 scale and producing line to vertical axis at right. Connect 0.6 on p_2 scale with 20 on t_2 scale and produce line to vertical axis at left. Line connecting intersections at right and left axes will cut S scale in desired value, 4.89 g. chlorine per 1,000 g. water. Since mol.wt. of chlorine is 7.091, S in g. of chlorine per 1,000 g. water equals 709.1 c.—*Ed.*

Nomograph for the Solubility of Sulfur Dioxide in Water. D. S. DAVIS. Ind. Eng. Chem. **33:** 730, 1376 (June, Nov. '41). Accompanying line co-ordinate chart (Fig. 2) was constructed by author from equation connecting pressure (partial pressure of SO_2 in mm. Hg) and temp. (°C.) to facilitate interpolation on convenient and reproducible basis for solubilities as g. SO_2/100 g. water over range 0.51, 1.09, 4.36 and 7.45 g. Elsewhere usually yields values between Beuschlein and Simenson data and those of *International Critical Tables* (**III:** 302 ('28)). Three temp. scales designed for use in 3 ranges of concns. Dashed index line shows soln. testing 2.5 g. SO_2/100 g. H_2O has partial SO_2 pressure of 428 mm. Hg at 50°C. Dotted temp. scale used because designated as proper scale for concns. embracing S = 2.5. In converse use of chart to find concn. corresponding to given temp. and partial pressure, proper temp. scale is one yielding concn. in range for which temp. scale marked.—*Ralph E. Noble.*

Experiments on the Removal of Arsenic, Vanadium and Fluorine From Water. ROGELIO A. TRELLES AND JOSE M. BACH. Bol. Obras Sanitarias Nacion. (Arg.) **5:** 243, 353, 469 (Mar., Apr., May '41). *Part 1. Elimination of Arsenic:* Fact that some deep well waters in Argentina contain arsenic, vanadium and fluorine, either singly or simultaneously, in conc ns. far above safe limit established for these elements in drinking water prompted search for practical methods of removal. Expts. with activated bauxite indicated impracticability of this method of treatment because of limited arsenic-fixing capac. of material. No better results obtained when attempt made to eliminate arsenic by

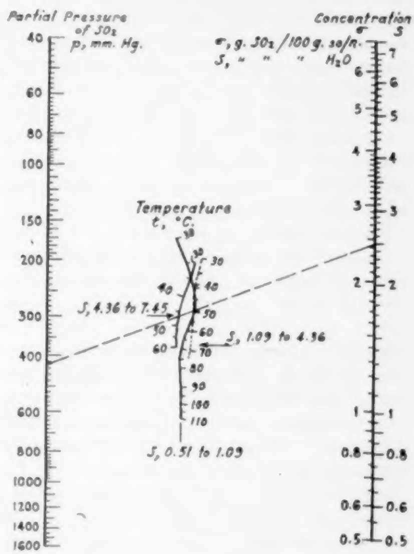


FIG. 2

use of "Fluorex," calcium phosphate used for fluoride removal. Formation of iron hydroxide ppt. by treating alk. waters with $FeCl_3$, proved effective for arsenic elimination. Dose of 40 ppm. FeCl sufficient to reduce arsenic concn. from 2.5 to 0.07 ppm. in water of pH 8.2 contg. 365 ppm. alky. Prolonged agitation with suspension of MgO proved ineffective for removal of arsenic from water at ordinary temps. Possible, however, to obtain excellent removal by bringing magnesia-treated water to bp. and allowing ppt. to settle out. Elimination of arsenic from carbonate- or

bicarbonate-contg. water also found possible by lime treatment. This procedure, however, does not seem practical because of large amts. of chem. needed to raise pH of water high enough for effective treatment. When $CaCO_3$, as such, added to water, no removal of arsenic obtained. Pptn. of magnesium hydroxide by treating magnesium-contg. waters with lime also found effective for arsenic elimination. *Part 2. Elimination of Vanadium:* Vanadium-fixing capac. of activated bauxite for water of pH 6.0 found to be on order of 10 mg. of vanadium per gram of filtering material. In alk. waters, activated bauxite only $\frac{1}{10}$ as efficient. Still more limited was vanadium-fixing capac. of "Fluorex." As in case of arsenic, good results obtained in alk. waters by use of $FeCl_3$. Dose of 30 ppm. $FeCl_3$ sufficient to reduce vanadium from 2.5 ppm. to trace in waters of pH 8.6 contg. 390 ppm. alky. as $CaCO_3$. Treatment with MgO not effective unless water brought to bp. Lime treatment of carbonate- or bicarbonate-contg. water found to be effective for removal of vanadium providing treated water brought to final pH of 12. Addn. of $CaCO_3$, as such, to water not effective. Pptn. of magnesium hydroxide by lime treatment of magnesium-contg. waters, also accomplished removal of vanadium. *Part 3. Elimination of Fluorine:* Results of study now in progress on use of activated bauxite for fluoride removal to be reported at a later date. In presence of 1.5 g./l. MgO possible to reduce fluoride concn. from 5.0 to 0.2 ppm. by bringing water to bp. Greater the bicarbonate content of water, the more complete the removal. Treatment of water contg. 100 ppm. of magnesium with lime to final pH of 12, reduced fluoride concn. from 5 to 3 ppm. Slightly better results obtained with waters of high bicarbonate concn. $CaCO_3$, as such, added to the water ineffective for fluoride removal.—*J. M. Sanchis.*

Vanadium, Its Determination in Waters. Jose M. Bach and Rogelio A. Trelles. Bol. Obras Sanit. Nacion. (Arg.) **5:** 127 ('41). Previously described method simplified to det. V without first sepg. Fe; 50 ml. of water made acid to Congo red with H_2SO_4; 5 drops of a soln. contg. 2½g. of *o*-hydroxyquinoline in 100 ml. of 20% soln. of citric acid, followed by shaking, 10 ml. of isoamyl alc. and shaking again. Alc. layer removed and colorimetrically compared with similarly treated std. solns. of $NaVO_3 \cdot 4H_2O$. Cu interferes.—*C.A.*

Report on Waters, Brine and Salt, Fluorine in Water. A. E. Mix. J. Assn. Off. Agr. Chem. **23:** 447 ('40). In continuation of previous work, detns. of concn. of fluorine by thorium nitrate titration method of Assn. made on 41 samples of artificial mineral water; avg. deviation of results from correct value (2.04 ppm.) was 0.23 ppm. fluorine. In previous expts. deviation 0.287 ppm. for 32 trials. Percentage errors for 2 series of expts., 7.5 and 3.3, resp. Method suggested by D. Dahle for detn. of fluorine in soln. of brine gave std. deviation of 1.18 ppm. and error of 8.5%. Method for anal. of brine differs from that for mineral waters in that, with brine, chlorides removed by oxidation with potassium permanganate instead of silver perchlorate, and concd. sulfuric acid instead of perchloric acid used to liberate hydrofluoric acid. Errors in thorium nitrate titration may be caused by incomplete removal of chlorides and presence of phosphate from commercial salt used. Distillate from artificial mineral water found to be highly acidic; effect of acidity on titration not known. 100-ml. sample of mineral water made alk. with sodium hydroxide became acid when evapd. down to 20 ml. During evapn., soln. should be kept alk. by addn. of sodium hydroxide. If Claissen flask overheated, perchloric acid disintegrates, giving hydrochloric acid, which dists. over. Hydrochloric acid also produced from chlorides; this should be removed from soln. by addn. of calcd. amt. of silver perchlorate.—*W.P.R.*

Report on the Analysis of Water, Brine and Salt. Determination of Fluorine in Water. A. E. Mix. J. Assn. Off. Agr. Chem. **24:** 540 ('41). Present Assn. Off. Agr. Chem. tentative Th nitrate titration method modified as follows: (1)

addn. of 1 ml. of 0.1% $NH_2OH \cdot HCl$ to aliquot titrate; (2) use of std. color comparison tube; (3) running blank on each distn. for F; (4) evapn. of sample before distn. in porcelain or Pt over Bunsen flame just below boiling point; (5) preliminary detn. of chlorides and pptn. in distg. flask with $AgClO_4$. Modified method studied collaboratively, results justifying changes. Method especially applicable to solns. contg. 1.00–3.00 ppm. F, in which range of expected error will be 3.3–416% and expected std. deviation 0.071–0.230.—*C.A.*

Determination of Small Amounts of Fluorine in Water. O. J. WALKER AND G. R. FINLAY. Can. J. Res. **18:** B: 151 ('40). Colorimetric method of Sanchis and titration method of Willard and Winter for detn. of fluorine in water modified to overcome interference of other dissolved substances. For titration method, sample, contg. approx. 0.2 mg. fluorine, made alk. to phenolphthalein with caustic potash soln. concd. to 50 ml. and distd. with acid at 110°C., water being added from time to time to maint. temp. of flask below 135°C. 20 ml. of concd. sulfuric acid normally used, but if more than 2 ppm. phosphates present, 30 ml. of 60% perchloric acid used. If content of phosphates very high, distn. first with sulfuric acid, then with perchloric acid, required. 75–100 ml. of distillate collected and made alk. to phenolphthalein with caustic potash soln. For titration in alc. soln., distillate concd. to 20 ml.; 20 ml. of ethyl alcohol and 3 drops of a 0.5% soln. of sodium alizarin sulfonate in water added and sufficient hydrochloric acid to change color from red to yellow. 2 ml. of Hoskins and Ferris buffer soln. added before titrating with std. thorium nitrate soln. in Nessler tube. For titration in aq. soln., distillate concd. to 50 ml., 3 drops of indicator and sufficient hydrochloric acid to change color to yellow added. 3 ml. buffer soln. added and soln. titrated with thorium nitrate soln. Effects of various ions which interfere with colorimetric detn. of fluorine given, and method described. Only colorless samples can be anald. by this method. 2 ml. of $3N$ hydrochloric acid, 2 ml. of $3N$ sulfuric acid, and 1.8 ml. of indicator added to 100 ml. of sample. Indicator contains 0.17 mg. sodium alizarin sulfonate and 0.87 mg. zirconyl nitrate per ml. Soln. heated to boiling, allowed to stand overnight, and compared with similarly treated solns. contg. known amts. of fluorine. Graphs given from which correction required for different quants. sulfate can be found. Solns. contg. more than 1.5 ppm. fluorine must be suitably dild. before use. Samples contg. more than 2 ppm. phosphates, aluminum, or ferric ions should be anald. by titration method. Results for 27 samples of water in Alberta with contents of fluorine between 0 and 4.4 ppm. given.—*W.P.R.*

A Photocolorimetric Method for the Determination of Fluorine. A. B. SHAKHKELDIAN AND E. SERDOBOVA. Uchenye Zapiski Saratov. Gosudarst. Univ. (U.S.S.R.) **15:** 4: 87 (in English, 93) ('40). Basis for detn. was decolorization of $Fe(CNS)_3$ soln. by addn. of alkali fluoride in accordance with equation: $6F^- + Fe(CNS)_3 = FeF_6^{---} + CNS^-$. Full details for carrying out detn. with aid of photoelec. cell given. Red light filter could not be used, but with blue light filter detn. of 0–3 mg. fluorine in 100 ml. aq. soln. accomplished within about 1.3% of truth, which is very good for these small quants.—*C.A.*

TITLE 32—NATIONAL DEFENSE

Chapter IX—War Production Board

Subchapter B—Division of Industry Operations

Part 960—Chlorine and Products Containing Available Chlorine

GENERAL PREFERENCE ORDER NO. M-19 AS AMENDED FEBRUARY 25, 1942—TO CONSERVE THE SUPPLY AND DIRECT THE DISTRIBUTION OF CHLORINE AND PRODUCTS CONTAINING AVAILABLE CHLORINE

The Amended Order which by its terms took effect immediately upon issuance contains the following new provisions in addition to those provisions of Amendment No. 1 to General Preference Order M-19 which are reincorporated in such Amended Order:

(1) The Order is applicable to products containing available Chlorine as well as to Chlorine which alone forms the subject of Amendment No. 1 to General Preference Order M-19.

(2) The use of Chlorine and of products containing available Chlorine in bleaching foodstuffs, bleaching of wiping rags and waste and the manufacture of cosmetics and toilet preparations is prohibited.

(3) The uses of Chlorine and of Chlorine products for certain other purposes is curtailed in varying percentages of the consumption for the corresponding purposes during the fiscal year ending June 30, 1941.

(4) Users of Chlorine or Chlorine products for potable water treatment and sewage treatment need no longer file with their suppliers Form PD-190, but are required instead to file a certificate to the effect that the Chlorine or Chlorine products so received will be used only for such purposes.

(5) Beginning March 1, 1942, all orders for products containing available Chlorine must be accompanied by PD-277, properly executed, except in the case of Chlorine products for water and sewage treatment and except when the quantity ordered is small (5 lb. in case of solids and one gallon containers in case of liquids).

(a) *Section 960.1 (General Preference Order No. M-19, as amended) is hereby amended to read as follows:*

WHEREAS, national defense requirements have created a shortage of Chlorine and products containing available Chlorine, as hereinafter defined, for the combined needs of defense, private account and export, and it is necessary in the public interest and to promote the defense of the United States, to conserve the supply and direct the distribution thereof;

Now, therefore, it is hereby *ordered* that:

960.1 *General Preference Order* (a) *Definitions.*

(1) "Chlorine" means gaseous and liquid Chlorine;

(2) "Products containing available Chlorine" means any product which readily releases Chlorine; such products include, but are not limited to, all combinations of Chlorine with caustic soda, soda ash, or lime, such combinations being commonly known by one or more of the following names: sodium hypochlorite, liquid bleach, true or high-test calcium hypochlorite, chlorinated lime, chloride of lime, bleaching powder, or sodium chlorite; and also includes solutions of any such products or any mixture containing one percent (1%) or more of any such products;

(3) "Producer" means any person engaged in the production of Chlorine or products containing available Chlorine, and includes any person who has such materials produced for him pursuant to toll agreement;

(4) "Distributor" means any person who purchases Chlorine or products containing available Chlorine for resale;

(5) "Supplier" means any Producer, Distributor or other person who sells or offers for sale Chlorine or products containing available Chlorine.

(6) "Base Period" means the period July 1, 1940 to June 30, 1941.

(b) *Restrictions on Use.*

(1) *Curtailment in certain uses.* Hereafter the use or consumption by any person of Chlorine and products containing available Chlorine shall be, in terms of Chlorine or available Chlorine content, curtailed or restricted in the following processes to the following quantities:

(i) In the manufacture of pulp and paper, to such quantity of such materials as are or may be required to comply with General Limitations Order No. L-11, or any supplement or amendment thereto,

(ii) In textile bleaching or processing, in any one calendar month commencing with March 1942 to not more than 50% of one-twelfth of such materials consumed by him during the base period.

(iii) In shellac bleaching and processing, in any one calendar month commencing with March 1942 to not more than 75% of one-twelfth of such materials consumed by him during the base period.

(iv) In linen-supply, hotel and commercial laundry operations, in any one calendar month commencing with March 1942 to not

more than 10% of one-twelfth of such materials consumed by him during such period.

(v) In the manufacture of sodium hypochlorite solutions for retail sale in containers of one-gallon capacity or less, in any one calendar month commencing with March 1942 to not more than 60% of one-twelfth of such materials consumed by him during the base period.

(vi) In sanitation of swimming pools, other than public and institutional swimming pools, in any one calendar month commencing with March 1942 to not more than 25% of one-twelfth of such materials consumed by him during the base period.

(vii) In the case of any person acquiring Chlorine or products containing available Chlorine for any use specified in this paragraph (b) (1), but who was not a consumer in the base period, his permitted consumption shall be in the same relative proportions hereinabove indicated but shall be based on his consumption during the month of September 1941 or such other period as may be directed by the Director of Industry Operations.

(2) *Prohibited uses.* Hereafter, the use or consumption by any person of Chlorine or of products containing available Chlorine is prohibited for any one or more of the following purposes: bleaching of foodstuffs, bleaching of wiping rags and waste, and manufacture of cosmetics and toilet preparations.

(c) *Placing Orders.* Anything in Priorities Regulation No. 1, as amended, to the contrary notwithstanding:

(1) No Producer of Chlorine shall, except as the Director of Industry Operations may otherwise direct, accept an order, whether it be that of a Distributor, another Producer, or a Consumer, for delivery of Chlorine unless such order has been placed with him on or before the 10th day of the month preceding the month in which delivery is sought, and unless such order is accompanied by Form PD-190 (in duplicate) properly executed by the person placing such an order. The Form PD-190 submitted by a Distributor must be accompanied by the original and one copy of each Form PD-190 submitted to him in accordance with paragraph (c) (2) hereof in connection with orders accepted by him.

(2) No Distributor of Chlorine shall, except as the Director of Industry Operations may otherwise direct, accept an order for delivery of Chlorine unless such order has been placed with him on or before the 5th day of the month preceding the month in which delivery is sought and unless such order is accompanied by Form PD-190 (in triplicate) properly executed by the person placing such order.

(3) No Producer or Distributor of Chlorine shall make, and no Person shall accept, delivery of Chlorine unless and until such Form PD-190 has been properly executed and timely filed in accordance with the provisions of paragraphs (c) (1) and (2) hereof.

(4) Each pulp and paper manufacturer requiring Chlorine, either purchased or his own production, in addition to filing Form PD-190 with his Supplier as provided in paragraph (c) (1) hereof, shall on or before the 15th day of the month preceding the month in which delivery is sought on said Form PD-190 file with the Pulp and Paper Branch of the War Production Board, Washington, D. C., Form PD-190A (in duplicate) properly executed, which shall list among other things the quantity of Chlorine ordered from each Supplier, the amount of his requirements to be supplied from his own production, if any, and his estimated distribution by use in pulp and paper manufacture of the total quantity of Chlorine ordered from others and produced by himself.

(5) No Supplier of products containing available Chlorine shall, commencing with March 1, 1942, except as the Director of Industry Operations may otherwise direct, accept an order, whether it be that of a Distributor, Producer or a Consumer, for delivery of such products unless such order is accompanied by Form PD-277, properly executed by the person placing such order. Such order, accompanied by the properly executed Form PD-277, may be placed with Supplier at the times and in the manner usually followed by such person in placing orders.

(6) Anything in paragraph (c) to the contrary notwithstanding, no Form PD-190 nor Form PD-277 need accompany any order for Chlorine or for products containing available Chlorine placed with a Supplier for use for potable water treatment and sewage treatment; however, in lieu of such Forms, the following certification, properly executed, should be inscribed on such orders:

> "*It is hereby certified by the undersigned that the Chlorine or products containing available Chlorine ordered hereon will, upon delivery, be used only for potable water treatment or sewage treatment or both.*

____
Purchaser

By ______________________
Signature of Official

____
Date *Title*

Also anything in paragraph (c) to the contrary notwithstanding, no Form PD-277 need accompany any order placed with retail outlets for products containing available Chlorine in liquid form in a container of one-gallon capacity or less or in solid form in a quantity of five pounds or less.

(d) *Withholdings From Scheduled Deliveries.*

(1) Each Producer of liquid Chlorine in scheduling in each calendar month beginning with February 1942 deliveries of liquid Chlorine to be made during the succeeding month shall withhold from scheduling for delivery five per cent (5%) of his total estimated production of liquid Chlorine for such succeeding month; and, except as provided in paragraph (d) (3) hereof no Producer shall make commitments for the sale or delivery during such succeeding month with respect to five per cent (5%) of such estimated production.

(2) In addition to the Chlorine withheld from delivery in accordance with paragraph (d) (1), each Producer who normally supplies liquid Chlorine for potable water treatment and sewage treatment shall also each month withhold from scheduling for other uses from the succeeding month's production a quantity of liquid Chlorine estimated to fulfill requirements for those purposes during such succeeding month. This quantity shall be distributed in such succeeding month for potable water treatment and sewage treatment in accordance with paragraph (e) (3).

(3) No Producer shall deliver liquid Chlorine as to which commitments may not be made pursuant to paragraph (d) (1) hereof, except upon express instructions of the Director of Industry Operations. If prior to the 15th day of the month in which a Producer is required by the provisions of paragraph (d) (1) hereof to withhold deliveries of liquid Chlorine, the Director of Industry Operations has issued no instructions with respect to the disposition of such liquid Chlorine, or if on such date it appears that any portion of the liquid Chlorine estimated to fulfill requirements for potable water treatment and sewage treatment by paragraph (d) (2) hereof will not be required for such purposes in such month, Producers may make deliveries of such liquid Chlorine without regard to the restrictions contained in paragraphs (b) and (c) hereof, or otherwise, except that the same shall be subject to the provisions of Priorities Regulation No. 1, as amended.

(e) *Delivery Schedules.*

(1) Each Producer of Chlorine shall, except as the Director of Industry Operations may otherwise direct, on or before the 15th day of each calendar month, file with the Chemicals and Allied Products Branch of the War Production Board, Washington, D.C. Form PD-191

(in duplicate) properly executed, which shall list among other things a schedule of deliveries of Chlorine which such Producer proposes to make in the succeeding month, the preference rating, if any, applicable to each delivery, the orders tendered to him for delivery during the succeeding month which he has not scheduled, his estimated production for the succeeding month and the amount of liquid Chlorine to be reserved for the succeeding month in accordance with the provisions of paragraphs (d) (1) and (2) hereof. Each original Form PD-191 shall be accompanied by a single copy of each Form PD-190 submitted to the Producer and listed on said Form PD-191. After such Forms have been filed with the Chemicals and Allied Products Branch of the War Production Board, any changes of circumstances or matters occurring thereafter affecting the accuracy of the statements contained in such Form PD-191 shall be forthwith reported to the Chemicals Branch of the War Production Board.

(2) On and after February 1, 1942, except as provided in paragraph (e) (3) hereof and except as may be otherwise specifically authorized by the Director of Industry Operations, Producers of Chlorine shall make no deliveries to any person unless and until the same shall have been authorized to do so by the Director of Industry Operations. Such authorization by the Director of Industry Operations shall be based primarily upon insuring the satisfaction of all defense requirements and providing an adequate supply for essential civilian uses. Each Producer of Chlorine shall, upon being apprised of the deliveries which have been authorized by the Director of Industry Operations, forthwith notify his customers of the extent of such authorization as the same may affect them. Each Distributor shall, upon being apprised by the Producer of the extent to which deliveries to such Distributor have been authorized by the Director of Industry Operations, forthwith notify his customers of the extent of such authorization as the same may affect them. If, however, by the 25th day of the month preceding the month in which deliveries are to be made, no instructions have been issued by the Director of Industry Operations, Producers may make deliveries of Chlorine in accordance with, and only in accordance with, the schedules filed by them with the Chemicals and Allied Products Branch of the War Production Board. Nothing in this paragraph contained shall require a Producer as a condition to making delivery of Chlorine for a use for potable water treatment or sewage treatment to obtain authorization by the Director of Industry Operations, nor shall a Producer or Distributor be required to notify his customer to whom delivery is to be made for either such use with respect to any such authorization.

(3) Producers of Chlorine shall in their usual manner, and whether directly to the Consumer or through their Distributors, distribute for potable water treatment and sewage treatment the liquid Chlorine withheld in accordance with paragraph (d) (2). In case of distribution through Distributors, the Distributors must, prior to delivery of Chlorine to them for either such purpose, certify that the Chlorine so delivered will not be distributed for any use other than potable water treatment or sewage treatment and will not exceed an estimated thirty-day supply for such purposes.

(4) Each distributor of products containing available Chlorine, other than a reseller through retail outlets of such products in liquid form in containers of one gallon capacity or less or in solid form in quantities of five pounds or less, shall, on or before the 5th day of each calendar month commencing with April 1942, file with his Supplier or Suppliers Form PD-278 properly executed, which shall list among other things a schedule of deliveries of such products made by such Distributor during the preceding calendar month, the particular product delivered, the use to which such product was devoted, and the inventory of such Distributor as of the first day of such calendar month.

(f) *Restrictions on Sales and Deliveries.*

(1) No Producer or Distributor shall knowingly sell or, directly or indirectly, deliver or cause to be delivered any Chlorine, or products containing available Chlorine, for any one or more of the uses specified in paragraph (b) (1) hereof in greater quantities than are therein specified or for any prohibited use; and no person shall accept deliveries of such materials for any one or more of the uses specified in paragraph (b) (1) in greater quantities than for permitted consumption and inventory or for any prohibited use.

(2) Nothing herein contained shall be construed to restrict any person to the same product or type of product, be it Chlorine or product containing available Chlorine, that he has heretofore purchased; provided, however, that the substitution or replacement of any one such product for or by another shall be made only on an equivalent available Chlorine basis.

(g) *Assignment of Preference Ratings.*

(1) For purposes of scheduling deliveries, defense orders which have not been assigned a higher preference rating are hereby assigned a preference rating of A-10.

(2) Unless a higher preference rating has been specifically assigned by order of the Director of Industry Operations, and subject to Priorities Regulation No. 1, as amended, orders for Chlorine and for products containing available Chlorine for the uses (or for the manufacture of

products for such uses) set forth below are hereby assigned the preference rating set opposite each such use as follows:

Use	*Preference rating*
Potable water treatment	A-2
Sewage treatment	A-2
Hospital, clinic and sanitoria sanitation	A-6
Dairy and other food processing plant sanitation	A-6
Public eating and drinking establishment sanitation	A-6
Public and institutional swimming pool sanitation	A-6
Sanitation in surgical and medical supplies manufacture	A-6
Diaper laundry sanitation and bleaching	A-6
Manufacture of products for medicinal, surgical, dental and veterinarian uses	A-6
Flour processing	A-9
Sugar refining	A-9
Foodstuff processing and refining other than bleaching not elsewhere classified	A-9
Food preservation	A-9
Use by Industrial, Research & Educational Laboratories	A-10
Manufacture of vitamin products	A-10
Manufacture of insecticides and fungicides	A-10
Manufacture of catalyst materials	A-10
Industrial water treatment	A-10
Metals refining	A-10
Petroleum production and refining	A-10
Processing of pulps, as follows:	
(a) High alpha pulps (not less than 90% alpha cellulose content)	B-2
(b) Dissolving pulps	B-2
(c) Nitrating Pulps	B-2
(d) Pulps used in manufacture of photographic base papers	B-2
(e) Pulps in which Chlorine is a processing rather than a bleaching chemical	B-2
Manufacture of petroleum product additives	B-2
Manufacture of industrial chemicals, coal tar chemicals, dyestuffs and intermediates	B-2
Manufacture of industrial plastics and rubberlike products	B-2
Pulp and paper bleaching not elsewhere classified	B-5
Textile bleaching and processing	B-5

Use	*Preference rating*
Shellac bleaching and processing	B-5
Laundry operations in linen supply, hotel and commercial laundries	B-5
Packaged products containing available Chlorine for retail sale	B-5
Sanitation of Swimming Pools not elsewhere classified	B-5
Foodstuff bleaching	Use prohibited
Wiping rag and waste bleaching	Use prohibited
Cosmetics and toilet preparation	Use prohibited

(h) *Intra-Company Transactions.* The prohibitions or restrictions contained in this Order with respect to acceptances of orders and deliveries in the absence of a contrary direction apply not only to acceptances of orders from and deliveries to other persons, including affiliates and subsidiaries, but also to acceptances of orders from and deliveries to one branch, division or section of a single enterprise by or from another branch, division or section of the same or any other enterprise owned or controlled by the same person.

(i) *Inventory Restrictions.* No Producer, or Distributor, shall make, and no person shall accept deliveries of Chlorine or products containing available Chlorine which will effect an increase (or a further increase) in said person's inventory of Chlorine or products containing available Chlorine beyond a thirty day supply thereof except as may be necessitated for reason of economic delivery.

(j) *Reports.* Each Producer and Distributor shall file with the Chemicals and Allied Products Branch of the Materials Division of the War Production Board such reports and questionnaires as said Office shall from time to time specify.

(k) *Records.* All persons affected by this Order shall keep and preerve for not less than two years accurate and complete records concerning inventories, production and sales.

(l) *Audit and Inspection.* All records required to be kept by this Order shall, upon request, be submitted to audit and inspection by duly authorized representatives of the War Production Board.

(m) *Appeal.* Any person affected by this Order who considers that compliance therewith would work an exceptional and unreasonable hardship upon him, may appeal to the Division of Industry Operations by addressing a letter to the Division of Industry Operations, War Production Board, Washington, D. C., setting forth the pertinent facts and the reasons such person considers that he is entitled to relief. The Director of Industry Operations may thereupon take such action as he deems appropriate.

(n) *Notification of Customers.* Producers and Distributors shall, as soon as practicable, notify each of their regular customers of the requirements of this Order, but failure to give such notice shall not excuse any person from the obligation of complying with the terms of this Order.

(o) *Applicability of Priorities Regulation No. 1.* This Order and all transactions affected thereby are subject to the provisions of Priorities Regulation No. 1 (Part 944), as amended from time to time, except to the extent that any provision hereof may be inconsistent therewith, in which case the provisions of this Order shall govern.

(p) *Communications to War Production Board.* All reports required to be filed hereunder, and all communications concerning this Order, shall, unless otherwise directed, be addressed to:

"War Production Board,
Washington, D.C. Ref: M-19"

(q) *Violations.* Any person who wilfully violates any provision of this Order, or who by any act or omission falsifies records to be kept or information to be furnished pursuant to this Order, may be prohibited from receiving further deliveries of any Material subject to allocation, and such further action may be taken as is deemed appropriate, including a recommendation for prosecution under Section 35 (A) of the Criminal Code (18 U.S.C. 80).

(r) *Effective Date.* This Order shall take effect upon the date of issuance thereof and shall continue in effect until revoked by the Director of Industry Operations subject to such amendments or supplements thereto as may be issued from time to time by the Director of Industry Operations.

(P. D. Reg. 1, amended December 23, 1941, 6 F. R. 6680; W. P. B. Reg. 1, Jan. 26, 1942, 7 F. R. 561, E. O. 9024, Jan. 16, 1942, 7 F. R. 329; E. O. 9040, Jan. 24, 1942, 7 F. R. 527; 527; sec. 2 (a), Public No. 671, 76th Congress, Third Session, as amended by Public. No. 89, 77th Congress, First Session.)

Issued this 25th day of February, 1942.

J. S. KNOWLSON
Director of Industry Operations

Applications for Project Ratings

THE methods to be used in filing applications for project ratings have been described at various times in previous issues of the JOURNAL (p. 1, News of the Field, October 1941; blue insert sheet, November 1941; p. 467, March 1942).

A more definite method of presenting the needs for material and the nature of a project is now set up. It requires the use of Form PD-200 and PD-200A (the reverse of PD-200). The content of these forms is shown herewith.

A project rating application must be made if a water department or company needs to add to its property a group of major facilities either for producing, pumping or distributing water.

Form PD-1A (see March Journal) should be used if the requirements are limited to a single assembled item such as a small pump and accessories or a line of pipe, valves and hydrants, etc.

If a project rating application is being filed for a water works extension, it is advisable to add to the completed forms, PD-200 and PD-200A, duplicate, bound statements prepared in accordance with the following outline:

The following information is required in the application for the granting of a project preference rating order covering project in the electric, gas, water, sanitation, central heating and telephone and telegraph communications, involving a number of separate contracts or suppliers.

1. Name of the operating company or agency.
2. The location of the project.
3. A clear, short statement of the scope of the project and its relation to any existing or proposed construction. A map showing the relation of the project to existing facilities is essential.
4. A comprehensive statement of the functional purpose of the project.
5. A statement with supporting data as to the relation of the project to national defense. A tabulation should be submitted showing volume, type and summary of major defense loads.

(*Text continued on page 656*)

OFFICE OF PRODUCTION MANAGEMENT
DIVISION OF PRIORITIES

APPLICATION FOR PROJECT RATING

To: Director of Priorities, Office of Production Management,
Washington, D.C.

Instructions for Preparation of Application for Project Rating

Fill out in quintuplicate and execute the Certification on the original copy. Retain the quintuplicate copy and send all other copies to the Division of Priorities (PD-200), Office of Production Management, Washington, D.C. Where space on the form is not sufficient to furnish the information required or additional relevant information, attach supplemental typewritten statement in quadruplicate. Applicant must be owner or lessee of site of proposed project.

DO NOT FILL IN	SERIAL No. .... PRIMARY INDUSTRIAL BRANCH ....

INSTRUCTION NO.	TO BE ANSWERED BELOW BY APPLICANT
1	Name of applicant.
2	Address of applicant.
3	Location of project.
4	Have you applied for a Government Certificate of Necessity? If so, identify complete reference.
5	Describe project in sufficient detail for complete identification, including— (*a*) Number of buildings. (*b*) Type of construction of each building.
6	Describe product or service to be produced by the project for which application is made.
7	State capacity of proposed project in terms of product or service to be produced.
8	Explain in detail relationship of such product or service to national defense, public health or safety, or Government-sponsored programs.
9	Is proposed project— (*a*) A new facility? (*b*) Addition to existing facility? (*c*) Remodeling of existing facility?
10	Is proposed project under construction? If so, state— (*a*) Date started. (*b*) Per cent of completion.
13	How is project being financed?
14	If project will increase manufacturing facilities, state— (*a*) What per cent of your total current business consists of orders rated A-10 or better? (*b*) What per cent of your current business, limited to the product(s) to be produced by the project, consists of orders rated A-10 or better? (*c*) Pattern of rated orders referred to in paragraph 14 (b), for example: 7 per cent—A-1-a; 10 per cent—A-2; 30 per cent—A-5; etc.
15	Explain in detail what consideration has been given to— (*a*) Temporarily using other available facilities (as vacant building). (*b*) Reconditioning existing facilities. (*c*) Increasing productiveness of present facilities (as by working additional shifts or otherwise gaining objectives of proposed project).
16	Identify and attach evidence (if any) of Federal, State, or local government endorsement of this application.

11	State estimated completion date of project.	17	Have you made other or previous application related to proposed project or any part thereof? If so, explain.
12	State estimated cost of project, exclusive of site.		

INSTRUCTION NO.	IDENTIFY EACH STATEMENT WITH CORRESPONDING INSTRUCTION NUMBER (SHOWN ABOVE)

The undersigned hereby certifies that he is authorized to execute this application on behalf of the applicant; that there is no omission of any material fact; that the facts herein set forth, or appended (including Critical Materials List PD-200A), are true and correct to the best of his knowledge and belief.

(Date) (Signature and title of authorized official)

Section 35 (A) of the United States Criminal Code, 18 U. S. C., Section 80, makes it a criminal offense to make a false statement or representation to any Department or Agency of the United States as to any matter within its jurisdiction.

(*Text continued from page 654*)

6. A statement of the urgency of *need* for the proposed construction, including estimates of existing and scheduled dependable capacities (and of reserve and net assured capacities in the case of electric utilities) and requirements for the next three years. In case of water and sewage treatment plants, the immediate need therefor shall be fully supported, preferably by summaries of analytical results and by a statement by the State Department of Health.

7. If inter-connections with neighboring utility systems exist, or are possible, state the extent and capacity to which they are or could be utilized, and the extent to which they could make available to others any capacity of applicant's system. If inter-connections exist and are not used, state why.

8. The latest practicable date of introduction of the project into commercial operation.

9. A statement of aggregate dollars cost of the project, and, where applicable, the remaining cost where the project is under construction, both exclusive of labor.

10. A schedule of the various larger elements entering into the project. For each element list the expected sources of procurement, the latest practicable delivery date, the estimated dollars cost, exclusive of installation labor. The aggregate dollars involved in these items should approximate 80 per cent of the total dollars involved in the project.

11. A careful estimate of the total and, where possible, the weight, of the critical materials involved in the entire project, such as copper, steel, cast iron and aluminum.

(*Text continued on page 660*)

PD-200A

Sample of Reverse of Quintuplicate Form

SERIAL NO. ....

CRITICAL MATERIALS LIST FOR PROJECT RATINGS

STRUCTURAL MATERIALS FOR ALL PURPOSES (incl. power plants)

Iron and Steel

1. Structural steel.[1]
2. Reinforcing steel.[1]
3. Steel mesh.[1]
4. Plates.[1]
5. Slabs.[1]
6. Bars.[1]

Sheets:

7. Sheet iron, black, uncoated.[2]
8. Sheet iron, flat, galvanized.[2]
9. Corrugated sheet iron, black, uncoated.[2]
10. Corrugated sheet iron, galvanized.[2]
11. Corrugated sheet iron, asphalt, protected.[2]
12. Forgings.[1]
13. Castings.[1]
14. Steel sash, window and frame.[3]
15. Steel bucks, door, etc., frames.[3]
16. All other iron and steel.[4]
17. ....
18. ....
19. ....
20. Nails.[4]
21. Sheet piling.[1]
22. Metal lath.[5]
23. Steel deck roofing.[6]
24. Tubing.[4]
25. Fence.[5]

Special steels:

26. Stainless.[4]
27. Chromium.[4]
28. ....
29. Conduit.[4]

Other Metals (Nonferrous)

30. Pipe, copper.[4]
31. Pipe, brass.[4]
32. Pipe, other (nonferrous).[4]

Sheet metal:

33. Roofing, flashing.[4]
34. Down spouting and gutters.[4]
35. Miscellaneous.[4]
36. Weather stripping.[4]
37. Screening.[4]

Aluminum:

38. Castings.[4]
39. Rolled.[4]
40. Extrusion.[4]
41. Powder.[4]
42. Screens.[4]
43. ....

Lead:

44. Sheet.[4]
45. Pipe.[4]
46. Pig.[4]

Tin:

47. Pig.[4]
48. Sheet.[4]
49. Other.[4]
50. Miscellaneous.[4]
51. ....
52. ....
53. ....

UTILITIES (including pumping, filtration system, etc.)

54. Sewage pipe, iron (lbs. per ft.........).[7]
55. Sewage pipe, steel (lbs. per ft.........).[7]
56. Fittings, as additional.[7]
57. Gas lines (material..............................) (lbs. per ft..........).[7]
58. Fittings as additional.[4]
59. Water pipe lines (material..................) (lbs. per ft..........).[7]
60. Fittings as additional.[4]
61. Steam lines (material ....) (lbs. per ft..........).[7]
62. Fittings as additional.[4]
63. Fuel lines (material..............................) (lbs. per ft..........).[7]
64. Fittings as additional.[4]
65. Electric lines (cuprous) (lbs. per ft..........).[7]
66. Fittings or appurtenances, additional.[4]
67. Electric lines, other.[7]
68. Fittings or appurtenances, additional.[4]
69. Conduit (material ....) (lbs. per ft..........).[7]
70. Conduit, fittings, etc., additional.[4]
71. Corrugated iron pipe, coated.[4]
72. Corrugated iron pipe, uncoated.[4]

MISCELLANEOUS FEATURES AND APPURTENANCES

73. Water storage (number of tanks, gage of metal, and dimensions and type).[4]
74. Gasoline storage (number of tanks, gage of metal, and dimensions and type).[4]
75. Other storage (number of tanks, gage, dimensions).[4]
76. Railroad track (weight of rail per ft. of rail). (Total rail length.)[8]
77. Electric lighting fixtures.[9]

Hardware:

78. Hardware—butts.[10]
79. Hardware—locks.[10]
80. Miscellaneous.[4]
81. ....
82. ....
83. Plumbing fixtures—w.c. (metals only).[9]
84. Plumbing fixtures—lavs. (metals only).[9]
85. Plumbing fixtures—bath tubs (metals only).[9]

86. Plumbing fixtures—misc. sinks (metals only).[9]
87. Other.
88. ....
89. ....
90. ....
91. ....

CEMENT AND CONCRETE

92. Cement or alternate.[11]
93. Concrete.[12]

Concrete masonry:

94. Lightweight—exposed.[13]
95. Lightweight—backing.[13]
96. Heavyweight—exposed.[13]
97. Heavyweight—backing.[13]
98. Concrete pipe.[8]
99. Average concrete per lin.ft.[14]
100. Average steel rods per lin.ft.[4]
101. Average steel mesh per lin.ft.[4]
102. Precast concrete roof slab (featherweight).[2]

CLAY PRODUCTS

103. Brick, refractory.[13]
104. Brick, other than refractory.[13]
105. Clay, refractory.[1]
106. Tile (partition and back-up).[13]
107. Glazed and facing tile.[13]
108. Clay pipe, glazed sewer pipe.[13]
109. Drain tile, unglazed.[13]

GYPSUM PRODUCTS

110. Sheathing board.[5]
111. Wall board.[5]
112. Lath.[5]
113. Plaster.[1]
114. Partition tile.[5]
115. Roof, precast.[5]
116. Roof, poured.[5]

LUMBER

117. Construction lumber 2 inches thick and under (including common boards and dimension).[15]
118. Construction lumber 3 inches thick or over.[15]
119. Finish lumber (including siding, interior finish, ceiling, paneling, etc.).[15]
120. Finish flooring.[15]
121. Window sash and window frames.[16]
122. Doors and door frames.[16]
123. Plywood, Douglas fir.[5]
124. Plywood, hardwood.[5]
125. Fibre board insulation (including Celotex, Insulite, etc.).[5]
126. Wall board, laminated.[5]
127. Wall board, hard (including Masonite, etc.).[5]
128. Tank and pipe stock.[15]
129. Piling, untreated.[8]
130. Piling, treated.[8]
131. Miscellaneous (such as poles, etc.).[8]
132. Railroad ties—untreated.[16]
133. Railroad ties—treated.[16]

INSULATING, ETC., MATERIALS

Cork and cork products:

134. Insulating board (thickness .... in).[15]
135. Other.[15]

Asbestos products:

Asbestos cement shingles:

136. Roofing.[2]
137. Siding.[2]
138. Corrugated asbestos cement sheets.[5]
139. Flat asbestos sheets.[5]
140. Ebonized asbestos.[5]

Asbestos cement pipe:

141. Under 8-inch.[8]
142. 8-inch to 12-inch.[8]
143. Over 12-inch.[8]

Magnesia and high temperature insulations:

Magnesia (85% Mg.) (200° to 600°F.):

144. Pipe covering.[17]
145. Blocks.[17]

High temperature (85% Mg.) (600° to 1900°F.):

146. Pipe covering.[17]
147. Blocks.[17]

MISCELLANEOUS EQUIPMENT

Heaters and boilers (low pressure):

148. Heating coils and convectors.[4]
149. Radiators, iron.[4]
150. Traps (material..........) (lbs. per..........).[4]
151. Pumps and miscellaneous machinery.
152. ....
153. ....
154. ....
155. ....
156. Unit refrigerators (air-conditioning systems not to be reported here, but under "Metals-Utilities").[3]
157. Ranges and stoves (cafeteria and other kitchen, etc., equipment under "Metals-Iron and Steel," and other).[3]

On items listed below valued at more than $10,000, give summary break-down and individual costs on a separate sheet.

POWER, GENERATING AND DISTRIBUTING EQUIPMENT

Steam:

158. Boilers.
159. Combustion equipment.
160. Pumps.
161. Compressors.
162. Turbines.

163. Steam generating equipment (N.E.C.).
164. Steam distribution equipment (N.E.C.).

Electric:

165. Motors.
166. Generators.
167. Transformers.
168. Convertors.
169. Other electrical generation equipment (N.E.C.).
170. Electrical transmission equipment (N.E.C.).

INDUSTRIAL EQUIPMENT

171. Machine tools.*
172. Material-handling equipment.
173. Manufacturing and processing machinery and parts (N.E.C.).
174. Laboratory equipment.

OFFICE EQUIPMENT

175. Business machines.
176. Other office equipment.

CHEMICALS (Specify)

177. ....
178. ....
179. ....
180. ....
181. ....
182. ....
183. ....
184. ....
185. ....
186. ....
187. ....
188. ....
189. ....
190. ....

Use the following units of measure for entry in column 2 below:

[1] Tons. [3] Units. [5] Sq.ft. [7] Ft. [9] Pcs. (or units). [11] Bbls. [13] M. [15] Bd.ft. [17] Sections.
[2] 100 Sq.ft. [4] Lbs. [6] Squares. [8] Lin.ft. [10] Sets or units. [12] Cu.yds. [14] Cu.ft. [16] Pcs.

* Fill in columns 3, 4, and 5 for informational purposes only. Preference ratings on machine tools must be applied for separately on Form PD-1.

Indicate only those materials for which substitutions of noncritical materials can not be made. In event construction has been started, list only those materials needed for the completion of the Project. (Do not list materials delivered to site or in transit.)

LIST OF MATERIALS NEEDED FOR PROJECT

ITEM (1)	UNIT OF MEASURE (2)	NUMBER OF UNITS (3)	VALUE (4)	DESCRIPTION OF USE (5)	**Applicant Leave Blank (6)**
- - - - - -	- - - -	- - - -	- - - -	- - - - - -	- - - -
- - - - - -	- - - -	- - - -	- - - -	- - - - - -	- - - -
TOTAL OF ALL CRITICAL MATERIALS......	x x x x x x x	x x x x		x x x x x x x x x x x x x	

(Space Below Not to Be Filled Out by Applicant)

SUBSTITUTIONS:

TOTAL OF SUBSTITUTIONS . . . . . $..........

TOTAL OF CRITICAL MATERIALS MINUS SUBSTITUTIONS . . . . . $..........

The items in the quantity listed in column 3, as they may be modified in column 6 and by the substitutions provided hereon, are hereby approved.

APPROVED BY:

....

Chief.

(..............................Branch)

....

(Date)

(*Text continued from page 656*)

The application should be a sworn statement by an executive officer of the applicant. All applications shall be submitted in the name of the operating company.

Applicant in cases of specific necessity, may ask at a later date for preference ratings on individual elements of the project higher than that assigned to the project, submitting such requests on form PD–1.

A project application is expected to cover *all* elements necessary to the effective use of the construction. For example, an application covering a transmission line should include switching equipment and transformers, and all appurtenances and accessories necessary to its use.

The application should be carefully prepared following the foregoing outline, and should include all pertinent information so as to present a complete and understandable picture of the project.

The application should be prepared on $8\frac{1}{2} \times 11$-inch paper and bound in a suitable folder. The applicant should mail *two* copies of the application, addressed to—J. A. KRUG, *Chief*, Power Branch, Office of Production Management, Social Security Building, Washington, D.C.

TITLE 32—NATIONAL DEFENSE

Chapter IX—Office of Production Management

Subchapter B—Priorities Division

Part 978—Utilities—Maintenance, Repair and Supplies

PREFERENCE RATING ORDER P-46 AMENDED TO MARCH 21, 1942

The War Production Board issued on March 26 a complete revision of Preference Rating Order P-46 which was issued last September to assist utilities in obtaining the minimum amount of materials necessary for maintenance, repair and operation. That order assigned a blanket preference rating of A-10 of such materials.

The order of March 26 supersedes the original order and all amendments thereto and makes several important changes, the principal of which are:

1. The blanket rating of A-10 in the original order is replaced by two higher ratings. An A-2 rating is granted to deliveries of material for maintenance, repair and operating supplies for power plants [production], and pumping plants. An A-5 rating is granted for all other facilities, such as lines, pipes and substations. One of the reasons for the distinction is that if a power plant or a pumping station breaks down, the whole system is put out of business. If a power line or a water pipe breaks, only a part of the system is affected. In either case, the rating is high enough to make possible prompt repair.

2. The order also assigns a rating of A-5 to deliveries of materials to bring electricity, gas, or water to war plants or other projects bearing a rating of A-5 or better. This does not apply to housing projects. An A-5 rating is also granted to deliveries of materials needed to protect power or water plants against sabotage, such as fencing, tear gas bombs for guards around such plants, etc. These ratings may not be applied without prior authorization from the Director of Industry Operations of the War Production Board.

3. Line extensions to serve a new consumer are restricted to 250 feet. The original order permitted a 1,000-foot extension. Extensions begun prior to March 26, the date of issuance of this order, may be completed.

Despite this restriction, the Power Branch of the WPB announced that

houses that were wired prior to March 26 or for which the foundations were completed by that date, may be served with electricity provided they are not more than 2,000 feet from an existing line and provided the utility specifies that galvanized steel wire will be used instead of copper.

This policy, which has been concurred in by the Steel Branch, will also permit extension of service to a number of homes which were already wired when the 1,000 foot extension limit was imposed last December 5.

The Power Branch made it clear, however, that extensions under this policy are not automatically approved, but that authorization must be obtained for each extension over 250 feet.

This policy will relieve special hardship cases where houses were wired in expectation of electric service which was subsequently denied because of material shortages. At the same time it will not result in the use of significant quantities of copper for line extensions. The Power Branch stated that the use of steel wire for electric extensions, in general, is concerned as an expedient only, and that customers served in this manner may not receive the most satisfactory class of service. It is felt, however, that this method of service in the special cases described is justified since this is the only means of providing electricity for these customers without the use of supplies of copper wire.

Two other changes in the order give utilities greater flexibility in obtaining delivery of materials.

1. Under the previous order restrictions were placed on the acceptance of deliveries of material in any quarterly calendar period. Often, through no fault of the utility, such materials were not delivered on the dates for which they were ordered. This provision has been changed to place the restriction not on the period in which materials are delivered but on the period in which they are scheduled for delivery.

2. Previously a utility could not obtain certain items which it needed if the dollar value of the items on hand within the same class exceeded a practical working inventory. This has been changed to permit a limited amount of deliveries of needed items.

PREFERENCE RATING ORDER P-46 AMENDED TO MARCH 21, 1942

Preference Rating Order P-46, as heretofore amended, is hereby amended to read as follows:

978.1—Preference Rating Order P-46

(a) *Definitions for the Purpose of this Order*

(1) "Producer" means any individual, partnership, association, corporation or agency, or any organized group of persons, whether incor-

porated or not engaged in, or constructing facilities for the purpose of engaging in, one or more of the following services, and includes any such Producer whether or not such Producer has applied the preference rating herein assigned:

(i) Supplying electric power directly or indirectly for general use by the public.

(ii) Supplying gas, natural or manufactured, directly or indirectly for general use by the public.

(iii) Supplying water directly or indirectly for general use by the public.

(iv) Supplying public sanitation services, but not including manufacturers of public sanitation products.

(v) Supplying central steam heating directly or indirectly for general use by the public.

(2) "Material" means any commodity, equipment, accessory, part, assembly, or product of any kind.

(3) "Maintenance" means the upkeep of a Producer's property and equipment in sound working condition.

(4) "Repair" means the restoration of a Producer's property and equipment to sound working condition after wear and tear, damage, destruction of parts, or the like have made such property or equipment unfit or unsafe for service.

(5) "Operating Supplies" means:

(i) Material which is essential to the operation of any of the industries or services specified above and which is generally carried in Producer's stores and charged to operating expense accounts.

(ii) Material for additions to or expansion of property or equipment provided that such additions to or expansion of property or equipment shall not include any work order job or project in which the cost of Material shall exceed $1500 in the case of underground construction and $500 in the case of other jobs and provided further that no single job shall be subdivided into parts in order to come below these limits.

(6) The terms "Operating Supplies," "Maintenance," and "Repair" include only Material which is essential to minimum service standards and do not include Material for the improvement of a Producer's property or equipment through the replacement of Material which is still usable in the existing installation with Material of a better kind, quality, or design.

(7) "Supplier" means any persons with whom a purchase order or contract has been placed for delivery of Material to a Producer or another Supplier.

(8) "Calendar Quarterly Period" means the quarterly periods commencing on the first day of the first, fourth, seventh, and tenth months of the calendar year and ending, respectively, on the last day of the third, sixth, ninth, and twelfth months of the calendar year, or the Producer's customary accounting periods closest to such periods.

(b) *Assignment of Preference Rating.* Subject to the terms of this Order the following Preference Ratings are hereby assigned:

(1) *Producers*

(i) A-2 to deliveries, to a Producer, of Material which is required by him for the Maintenance and Repair of production and pumping plant facilities, and to deliveries of Operating Supplies for such facilities.

(ii) A-5 to deliveries, to a Producer, of Material required by him for the Maintenance and Repair of all other facilities, and to deliveries of Operating Supplies for such facilities.

(iii) Subject to the provisions of paragraph (e) (2) A-5, to deliveries, to a Producer, of Material required by him for the construction of transmission, switching and distribution facilities necessary to serve new projects (other than housing projects) bearing a rating of A-5 or better.

(iv) Subject to the provisions of paragraph (e) (2), A-5 to deliveries, to a Producer, of Material required by him for protection against sabotage, provided such protection is directed by an authorized federal or state agency.

(2) *Suppliers*

(i) A-2 to deliveries, to any Supplier, of Material required by the Producer for any of the purposes specified in paragraph (b) (1) (i) or to be physically incorporated in such Material so required by the Producer.

(ii) A-5 to deliveries, to any Supplier, of Material required by the Producer for any of the purposes specified in paragraph (b) (1) (ii) or to be physically incorporated in such Material so required by the Producer.

(iii) A-5 to deliveries, to any Supplier, of Material required by the Producer for any of the purposes and within the limits specified in paragraphs (b) (1) (iii) and (b) (1) (iv) or to be physically incorporated in such Material so required by the Producer.

(c) *Persons Entitled to Apply Preference Ratings.* The preference ratings hereby assigned may, in the manner and to the extent hereby authorized, be applied by:

(1) a Producer;

(2) any Supplier, provided deliveries to a Producer or another Supplier are to be made by him, and are of the kind specified in paragraph (b) and have been rated pursuant to this Order.

(d) *Restrictions on Use of Rating.*

(1) *Restrictions on Producer and Supplier.* The preference ratings hereby assigned shall not be applied by a Producer or Supplier:

(i) unless the Material to be delivered cannot be secured when required without such rating;

(ii) to obtain deliveries of scarce Material, the use of which could be eliminated without serious loss of efficiency by substitution of less scarce Material or by change of design.

(2) *Restrictions on Supplier.*

(i) No Supplier may apply the rating to obtain Material in greater quantities or on earlier dates than required to enable him to make on schedule a delivery rated hereunder or, within the limitations of (ii) and (iii) below, to replace in his inventory Material so delivered. He shall not be deemed to require such Material if he can make his rated delivery and still retain a practicable working minimum inventory thereof; and if, in making such delivery, he reduces his inventory below such minimum, he may apply the rating only to the extent necessary to restore his inventory to such minimum.

(ii) A Supplier who supplies Material which he has in whole or in part manufactured, processed, assembled or otherwise physically changed may not apply the rating to restore his inventory to a practicable working minimum unless he applies the rating before completing the rated delivery which reduces his inventory below such minimum.

(iii) A Supplier who supplies Material which he has not in whole or in part manufactured, processed, assembled, or otherwise physically changed may, in restoring his inventory to a practicable working minimum, defer applications of the rating hereunder to purchase orders or contracts for such Material to be placed by him until he can place a purchase order or contract for the minimum quantity procurable on his customary terms; provided, that he shall not defer the application of any rating for more than three months after he becomes entitled to apply it.

(e) *Application of Preference Rating.*

(1) The Producer and each supplier, in order to apply the preference ratings to deliveries to them, must endorse the following statement, which must be applied on original and all copies of each purchase

order or contract for Material, the delivery of which is entitled to the preference rating hereby assigned;

> "Rating A-————. Material to be delivered pursuant to paragraph (b) ———— of Order P-46, Utilities Maintenance, Repair, and Suppliers, with the terms of which I am familiar.
>
> ________________________________
> *(Name of Producer or Supplier)*
>
> ________________________________
> *(Signature of Designated Official)*"

Such endorsement shall be manually signed by a responsible official duly designated for such purpose by such Producer or Supplier or in facsimile form in accordance with Priorities Regulation No. 7, (7 F.R. 1062), and shall constitute a representation to the War Production Board that such Material is required pursuant to the paragraph specified in the endorsement, and that the application of the rating is authorized by this Order.

(2) In addition to the requirements of paragraph (e) (1), a Producer in order to apply the preference rating assigned by paragraphs (b) (1) (iii), and (b) (1) (iv), must communicate with the Power Branch, War Production Board, Washington, D.C., Ref.: P-46 supplying in detail the following information:

(i) Description of the project to be built by the Producer.

(ii) Relation to military needs, war production, public health or safety.

(iii) Copy of customer's rating certificate or order, and in case of antisabotage materials, copy of order of federal or state agency.

(iv) Whether service can be rendered in any other way, or by any other Producer, with use of smaller quantities of critical materials.

(v) Cost of materials.

(vi) Total cost of Producer's project.

(vii) List of materials required for the construction. The Director of Industry Operations will notify the Producer whether and to what extent the application is approved. A copy of such notification shall be furnished by the Producer to any Supplier to evidence the proper rating granted pursuant to the provisions of this Order.

(3) A Supplier who has received from two or more Producers or Suppliers endorsed purchase orders or contracts for Material to the delivery of which the same rating has been applied in accordance with this Order, may include in a single purchase order or contract, and (within the limitations of paragraph (d) hereof) may apply the rating

to any or all of the Material which he in turn requires to make such rated deliveries or to replace in his inventory Material so delivered.

(4) In addition to the records required to be kept under Priorities Regulation No. 1, the Producer, and each Supplier placing or receiving any purchase or contract rated hereunder, shall retain, for a period of two years, for inspection by representatives of the War Production Board, endorsed copies of all such purchase orders or contracts, whether accepted or rejected segregated from all other purchase orders or contracts or filed in such manner that they can be readily segregated for such inspection.

(f) *Restrictions on Deliveries, Withdrawals, and Inventory.*

(1) No Producer shall, in placing orders, schedule for delivery to him in any calendar quarterly period any items of Material (whether or not rated pursuant to this Order) to be used as Operating Supplies or for Maintenance or Repair or any other purpose, the aggregate dollar volume of which shall exceed 25% of the aggregate dollar volume of the withdrawals of items of Material of the same class from stores or inventory during the calendar year 1940.

(2) No Producer shall at any time accept deliveries (whether or not rated pursuant to this Order) of any item of Material to be used as Operating Supplies or for Maintenance or Repair or any other purpose until the Producer's inventory and stores of items of Material of the same class have been reduced to a practical working minimum. Such minimum shall in no case exceed the aggregate dollar volume of items of Material of the same class inventory and stores on the most recent date during the calendar year 1940 on which the Producer's inventory was taken.

(3) No Producer shall

(i) during any Calendar Quarterly Period, make withdrawals from stores or inventory of any items of Material to be used as Operating Supplies or for Maintenance or Repair or for any other purpose, the aggregate dollar volume of which shall exceed the aggregate dollar volume of the withdrawals of such items of Material of the same class during the corresponding quarter of 1940, or at Producer's option, 25% of the aggregate dollar volume of the withdrawals of such items of Material of the same class during the calendar year 1940.

(ii) make withdrawals from stores or inventory of Material to be used for additions to or expansion of property or equipment, and no Producer shall, in the case of contract construction, accept delivery of Material for such purposes, unless

(a) the Producer's job or project is under construction and

40% of the total dollar value of the construction thereof was installed on December 5, 1941; or

(b) the cost of Material for the work order, job, or project is less than $1500 in case of underground construction and $500 in the case of other jobs; *provided*, however, that no single work order, job, or project shall be subdivided into parts in order to come below these limits, that in no event shall lines for the connection of new consumers be extended more than 250 feet from existing facilities, and that no addition to such extension shall be made within 90 days of the completion thereof.

(4) Notwithstanding the provisions contained in paragraphs (f) (1) (2) and (3), a Producer may:

(i) in any Calendar Quarterly Period increase the aggregate dollar volume of scheduled deliveries of Material for the Maintenance and Repair of, and for Operating Supplies, for, generation, production, and pumping facilities, and withdrawals of Material for such use over the limits prescribed in paragraphs (f) (1) and (f) (3) respectively proportionately to the increase in system output in the preceding Calendar Quarterly Period over the system output in the calendar quarter of 1940 corresponding to such preceding Calendar Quarterly Period; and

(ii) schedule for delivery in any Calendar Quarterly Period items of Material which will increase the aggregate dollar volume of inventory of Material for the Maintenance and Repair of, and for Operating Supplies for, generation, production and pumping facilities over the aggregate dollar volume of Material in inventory on the most recent date during the calendar year 1940 on which the Producer's inventory was taken, proportionately to the increase in system output during the preceding Calendar Quarterly Period over the system output in the Calendar Quarterly Period of 1940 corresponding to such preceding Calendar Quarterly Period; and

(iii) schedule for delivery to him in any Calendar Quarterly Period consumers' meters and house-regulators or make withdrawals from stores or inventories of such meters and house-regulators in an amount not in excess of 25% of the number of such meters or house-regulators condemned and destroyed by the Producer in 1940, (or, at the Producer's option, not in excess of the number of such meters and house-regulators condemned and destroyed in the corresponding quarter of 1940) plus the number of meters and house-regulators necessary to serve the net increase in customers occurring in the current quarter. For the purposes of

this subparagraph (iii), withdrawals of meters and house-regulators shall not include meters or house-regulators put in service to replace meters and house-regulators removed from service; and

(iv) in order to provide Material for unavoidable and emergency situations in cases where the inventory of a class of Material exceeds a practical working minimum, accept in any Calendar Quarterly Period deliveries of any short item of Material within such class, such deliveries, however, not to exceed 5% of the dollar volume of withdrawals of Material of the same class in the calendar year 1940; and

(v) schedule Material for delivery in any Calendar Quarterly Period, or accept deliveries, or make withdrawals in such period of Material necessary for the Maintenance or Repair of the Producer's property or equipment which is damaged by acts of the public enemy, sabotage, explosion, fire, flood or other climatic conditions, *provided*, that if the restrictions in paragraph (f) (1) (2) or (3) as modified by the provisions of paragraph (f) (4) (i) (ii) (iii) and (iv) are exceeded because of the scheduling or acceptance of such deliveries, or withdrawals, or full report therefor together with reasons therefor shall be made immediately to the Director of Industry Operations.

(5) The Director of Industry Operations may, on the application of any Producer, authorize such Producer to exceed the restrictions on deliveries, withdrawals, and inventories set forth in this paragraph (f). Nothing herein contained shall be construed to affect in any way any specific authorizations or approvals issued by the Director of Industry Operations pursuant to Preference Rating Order P-46 prior to the effective date of this Amendment.

(6) The provisions of this paragraph (f) shall not apply

(i) to Material obtained through the application of the rating assigned in paragraphs (b) (1) (iii) and (b) (1) (iv) or to Material withdrawn from stores or inventory for the purposes specified in said paragraphs.

(ii) to fuel, water purification chemicals, wooden poles or wooden crossarms.

(g) *Audits and Reports.*

(1) Each Producer and each Supplier who applies the preference ratings hereby assigned, and each person who accepts a purchase order or contract for Material to which a preference rating is applied, shall submit from time to time an audit and inspection by duly authorized representatives of the War Production Board.

(2) Each Producer and each such Supplier shall execute and file with

the War Production Board such reports and questionnaires as said Office shall from time to time request. No such reports shall be filed until such time as the proper forms are prescribed by the War Production Board.

(3) Each Producer shall maintain a continuing inventory of Material included in stores accounts.

(h) *Communications to War Production Board.* All reports required to be filed hereunder and all communications concerning this Order, shall, unless otherwise directed, be addressed to:

"War Production Board
Washington, D.C. Ref: P-46"

(i) *Violations.* Any Person who wilfully violates any provision of this Order or who by any act or omission falsifies records to be kept or information to be furnished pursuant to this Order may be prohibited from receiving further deliveries of any Material subject to allocation, and such further action may be taken as is deemed appropriate, including a recommendation for prosecution under Section 35 (A) of the Criminal Code (18 U. S. C. 80).

(j) *Revocation or Amendment.* This Order may be revoked or amended at any time as to the Producer or any Supplier. In the event of revocation, deliveries already rated pursuant to this Order shall be completed in accordance with said rating, unless the rating has been specifically revoked with respect thereto. No additional applications of the rating to any other deliveries shall thereafter be made by the Producer or Supplier affected by such revocation.

(k) *Applicability of Priorities Regulation No. 1.* This Order and all transactions affected thereby are subject to the provisions of Priorities Regulation No. 1, as amended from time to time, except to the extent that any provision hereof may be inconsistent therewith, in which case the provisions of this Order shall govern.

(l) *Effective Date.* This Order shall take effect immediately and shall continue in effect through June 30, 1942, unless sooner revoked.

Issued this 26th day of March, 1942.

(signed)
J. S. KNOWLSON,
Director of Industry Operations